Volume 25 APRIL, 1951 Number 3

IOWA STATE COLLEGE JOURNAL OF SCIENCE

A Quarterly of Research

CONTENTS

PUBLISHED BY
THE IOWA STATE COLLEGE PRESS
PRESS BUILDING
AMES, IOWA

IOWA STATE COLLEGE
JOURNAL OF SCIENCE

Published October, January, April, and July

Manuscripts should be submitted to George F. Stewart, Agricultural Experiment Station, Iowa State College, Ames, Iowa.

All matter pertaining to subscriptions, remittance, etc., should be addressed to the Iowa State College Press, Press Building, Ames, Iowa. Subscriptions are as follows: Annual: $6.00; (in Canada $6.50; other foreign countries ($7.00); single copies: $2.00 (Except Vol. XXV, No. 2—$3.00).

Entered as second-class matter January 16, 1935, at the post office at Ames, Iowa, under the act of March 3, 1879.

THE LEGUMINOSAE OF THE NORTH-CENTRAL UNITED STATES: I. LOTEAE AND TRIFOLIEAE[1]

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Received October 2, 1950

Legumes and grasses with respect to their importance in American agriculture, rank well ahead of other economic plant groups. The majority of agricultural plant scientists, whether engaged in teaching or research, are concerned at least in part with grasses or legumes. Their work frequently necessitates employment of fundamental information in regard to the classification and distribution of these plants.

The cultivated and native grasses have been investigated by a number of plant taxonomists, and the United States Department of Agriculture and various state experiment stations have contributed to such studies. Although present knowledge is far from complete, there is available a considerable volume of literature on the grasses of the United States, including Hitchcock's (28) standard text which is now being revised to meet continuing demand.

In comparison with grasses, legumes have received meager attention. Legume specialists have been relatively few in number and most of them have limited themselves to a few genera. There is no general treatment of the legumes of the United States comparable to Hitchcock's manual of the grasses. The present series of studies is aimed to provide a usable reference treatment for the legumes of the north-central United States.[2]

Plants treated in this paper include twenty-four cultivated, introduced-naturalized or native species of the Trifolieae and Loteae.[3] In a few cases, it was difficult to decide whether certain species should be considered to be representatives of the flora of the north-central states. In general, the plants included meet one or both of the following criteria: (a) the species (either native or naturalized) can be found in a region large enough to indicate a relative degree of permanence, (b) the species is commercially cultivated or is under active investigation for possible commercial use. On this basis several species, which have been casually introduced but which have shown little tendency to persist, have been

[1] Journal paper No. J-1840 of the Iowa Agricultural Experiment Station, Project 1073.

[2] That portion of the United States which is arbitrarily termed the north-central states is delimited in Fig. 1.

[3] The association of these two tribes does not imply that they are considered to be closely related—although they have been so judged by some authors. They are brought together merely as a matter of convenience.

excluded. These are briefly discussed under the heading, Excluded Species (page 478).

Treatments of genera and species include the following items: (a) Scientific name. Synonyms are limited to those names which have been employed in recent American literature. (b) Common English names. (c) Description. (d) Distribution, i.e., where native, world distribution, occurrence in north-central states. (e) Habitat characteristics and abundance. The following additional points are pertinent to some species and are discussed if information is available: (a) Taxonomic problems relating to the proper classification and identification of the species in question. Special attention is given to those species which are frequently confused with others. (b) Intra-specific variability and a summary of subspecific catagories. (c) Nomenclatorial problems — included only if name application is controversial. (d) Pollination and crossing mechan-

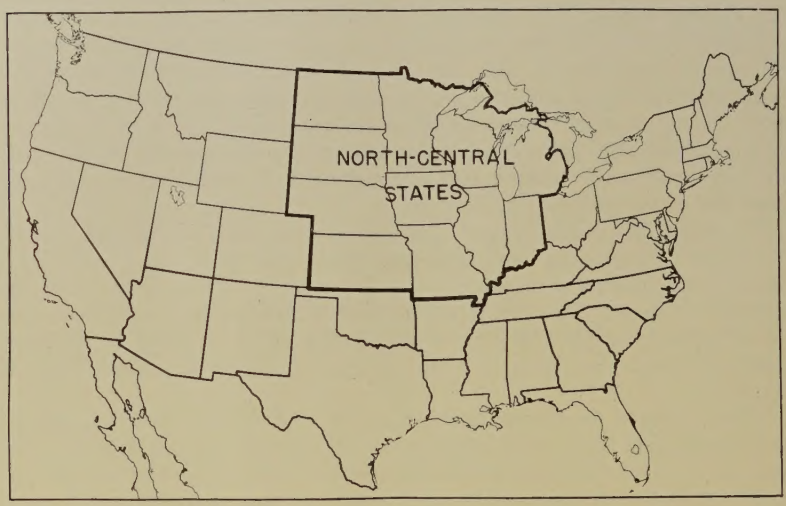

FIG. 1.—North-central states.

isms — described in detail for three representative species. (e) Chromosome number. (f) Agricultural employment. (g) Brief history of usage by man. (h) Agronomic varieties.

The analytical keys will allow identification of plant specimens in flower or in vegetative condition (except that the two species of *Melilotus* are nearly indistinguishable before flowering). When possible, both vegetative and floral characters are included in the same key. In some cases, it was necessary to prepare two keys, one for flowering or fruiting specimens, and a second based exclusively on vegetative characters.

Abbreviated literature citations are given for each genus. These

references indicate the more important works giving supplementary information about the genera in question, particularly the species found in the north-central states. Several European studies are cited, since they treat many of our introduced species more completely than any American manual. All references are given in full in the bibliography at the end of the paper.

ACKNOWLEDGEMENTS

These studies were made possible through employment of specimens from the following herbaria: Iowa State College, State University of Iowa, University of Wisconsin, Depauw University, University of South Dakota, New York Botanical Garden, Gray Herbarium of Harvard University, Missouri Botanical Garden, U. S. National Musem, and the Chicago Museum of Natural History. I wish to thank the officials of these institutions who made arrangements for loan of specimens, or who allowed me use of their facilities. Dr. John M. Winter, University of South Dakota, and M. D. Atkins furnished valuable information concerning the occurrence of *Trifolium beckwithii* in South Dakota. Help was received from the libraries of Iowa State College and the Chicago Museum of Natural History in various bibliographic matters.

Particular acknowledgement is due Mrs. Evelyn Smith who prepared the illustrations.

KEY TO TRIBES (PLATE I)

1. Leaflets entire; stipules rudimentary or glandlike; flowers in umbellate clusters or solitary; all filaments, or alternate ones, dilated above, frequently of two different lengths; pods several-seeded, usually dehiscent (Figs. 3, 4) LOTEAE
1. Leaflets toothed; stipules conspicuous; flowers in axillary racemes or capitate, occasionally in 2–3 flowered clusters; filaments similar or inner ones slightly the shortest; pods various, indehiscent or breaking irregularly (Figs. 1, 2) TRIFOLIEAE

LOTEAE

Mostly annual or perennial herbs. Leaves compound with 3–15 leaflets or occasionally simple; leaflets variously arranged. Stipules inconspicuous. Flowers umbellate or solitary. Stamens diadelphous (e.g. *Lotus*) or monadelphous (e.g. *Anthyllis*), the filaments usually dilated apically, or the alternate ones shorter and not dilated.

The Loteae is a relatively small tribe of somewhat uncertain relationships. It is frequently — but probably incorrectly — associated with the Trifolieae. Of approximately 150 species, the majority are in the genus *Lotus* (including *Hosackia*). *Anthyllis* and *Dorycnium* are the other major genera. Except for the western American representatives of *Lotus* the tribe is Eurasian; there is only one genus in our area.

LOTUS L.

(Incl. *Hosackia, Acmispon, Tetragonolobus*)

Plants perennial or annual. Leaflets 1–15, pinnately or palmately foliolate. Stipules[4] small or glandlike. Flowers in pedunculate, axillary clusters or solitary, yellow, white, or red. Keel petals generally fused both above and below. Stamens diadelphous. Style curved. Pod oblong, several-seeded, dehiscent.

Lotus contains perhaps a hundred or more species divided between western North America and the Mediterranean region of Eurasia and adjacent Africa. The natural range of some of the species has been greatly extended through the activities of man; this is particularly true of *L. corniculatus* which is now found on every continent.

The generic limits of *Lotus* are variously interpreted. Most European workers relegate the American species to the genera *Hosackia* or *Acmispon* and consider *Lotus* to be strictly an old world genus. They frequently further subdivide the genus through exclusion of those species with wing-angled pods (*Tetragonolobus*). American students

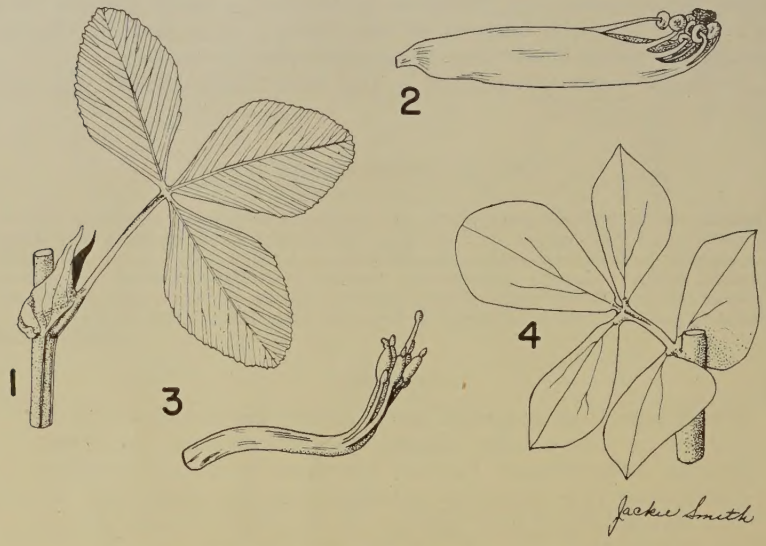

PLATE I, TRIFOLIEAE AND LOTEAE

Trifolium hybridum, 1. Leaf and stipule x 1½. *Medicago sativa*, 2. Stamens x 6. *Lotus corniculatus*, 3. Stamens x 6. 4. Leaf x 2.

[4] Some authors interpret the lowest pair of leaflets on the blade rachis as stipules. Others believe the stipules to be reduced and present only as small appendages on each side of the petiole attachment to the stem. The writer favors the latter hypothesis. However, morphological evidence has not yet given us a clear-cut answer.

are divided in opinion. Some consider our species to be congeneric with the European species of *Lotus* while others segregate them. The problem is discussed in some detail by Ottley (51,52). She notes that differences between various groups of American species are more extensive than those between the American and European species, further, that transition species link nearly all of the small subdivisions of related species. If the differences between the European and American species are worthy of generic status, then segregation of the American species into at least three genera would appear mandatory. This latter course of action appears unwise.

Basic chromosome numbers of both 6 and 7 occur in this genus. Senn (64) notes that the number 6 is restricted to the section *Eulotus* (to which *L. corniculatus* and relatives belong) while four other European sections possess a basic number of 7.

LITERATURE

Brand, (6), monograph
Gams, (23, 1364–76), European spp.
Hayek, (26, 877-83), Balkan spp.
MacDonald, (41), cultivated spp.
McKee, (46, 711–12), cultivated spp.
——— and Schoth, (48), cultivated spp.
Ottley, (51), California spp.
———, (52), monograph, sec. Simpeteria
Robinson, (60), cultivated spp.
Rydberg, (61, 461), central U. S. spp.; as *Acmispon*
Senn, (64, 222–28), chromosome numbers
Tome and Johnson, (66), *L. corniculatus*, relationships

KEY TO SPECIES (PLATE II)

1. Leaves 3-foliolate; flowers usually solitary; plant annual (Fig. 7).
LOTUS PURSHIANUS (page 447)
1. Leaves 5-foliolate; flowers 3–12, in umbellate clusters; plants perennial (Figs. 2, 3 and 4).
2. Plants with creeping rhizomes; umbels 8–12 flowered; calyx teeth divergent in bud (Figs. 5, 6). *L. MAJOR* (page 446)
2. Plants not possessing creeping rhizomes; umbels 3–7 flowered; calyx teeth appressed in bud (Figs. 1, 2).
3. Leaflets less than half as broad as long, linear to lanceolate (Fig. 4).
L. TENUIS (page 448)
3. Leaflets about half as broad as long or broader, obovate to lanceolate (Fig. 3).
L. CORNICULATUS (page 443)

LOTUS CORNICULATUS L. Birdsfoot trefoil (Plate II, Figs. 1–3)

Plants perennial from a stout crown; rhizomes not present. Stems decumbent or erect, up to 6 dm. in height, glabrous or pubescent. Leaves pinnately 5–foliolate, the lower pair of leaflets basally placed on rachis, the remaining three apical. Leaflets obovate to lanceolate in shape. Peduncles axillary, exceeding leaves. Umbels 3–8 flowered. Pedicels very short. Flowers usually 12–16 mm. in length. Calyx lobes approximating the tube, appressed in bud. Corolla yellow to orange-red; standard as broad as long, exceeding wings and keel. Pods 2–3.5 cm. long,

terete, straight; valves brown, splitting apart and twisting at maturity. Seeds about 1.5 mm. across, assymetrically rounded, dark- or olive-brown in color, frequently mottled or speckled.

Lotus corniculatus occurs throughout Europe, with the exception of the northern extremity, much of western Asia, North Africa, Australia, New Zealand, and scattered areas in North America. Before the intervention of man, it was probably limited to southern Europe. In North America it is now locally abundant as an escape and is becoming increasingly common in cultivation. It occurs in all of the north-central states, primarily in farm or experimental plantings.

Lotus corniculatus is a variable species. European treatments of

PLATE II, *LOTUS*

Lotus corniculatus, 1. Flower x 3. 2. Umbel x 1. 3. Leaf x 2. *Lotus tenuis*, 4. Leaf x 2. *Lotus major*, 5. Flower x 3. 6. Rootstock x 1. *Lotus purshianus*, 7. Leaf and flower x 3.

this plant subdivide it into numerous subspecific categories. Clarification of conflicting interpretations can be accomplished only after a thorough monographic study. Only certain tentative generalizations are presented below.

Among the several variants of birdsfoot trefoil which have been introduced into the United States are plants with narrower leaflets and slightly smaller flowers than the so-called typical variety. Such plants are classified as variety or subspecies, *tenuifolius* L., by most European authors. However, evidence is now available which indicates the probable specific status of this taxon. Tome and Johnson (66) have demonstrated that the narrow- and broad-leaved forms are incompatible and will not cross. The somatic chromosome number of typical *L. corniculatus* is 24, that of the narrow-leaved variety 12. On the hypothesis that broad-leaved *L. corniculatus* might represent an autotetraploid *tenuifolius,* these authors grew colchicine-produced autotetraploid plants of var. *tenuifolius* to maturity. These plants were morphologically different than typical *corniculatus;* further, this autotetraploid *tenuifolius* would not cross with *corniculatus.* In view of the fact that these two types of birdsfoot trefoil are easily distinguishable, and, as shown above, as they do not cross and blend together, their recognition as separate species seems justified. The narrow-leaved form is treated below as *Lotus tenuis* Kit.

For a complete classification of subspecific forms included under *Lotus corniculatus* see McKee and Schoth (48) or Gams (23). The names most frequently applied to varieties receiving attention in the United States are (1) var. *vulgaris* Koch, the common, ascending, large-leaved form, (2) var. *arvensis* (Pers.) Ser., plants decumbent, (3) var. *hirsutus* Koch, plants hairy with small leaves.

Lotus corniculatus is essentially self-sterile. The pollination mechanism is somewhat different than that possessed by other legumes which have been studied in detail. The keel petals are fused on both sutures and completely enclose the stamens and style except for a subapical pore or slit on the top side. The stamens are of two alternately placed kinds, one with long filaments, the other with short. The anthers dehisce before the flowers have completely opened; those of the longer stamens enlarge apically and together form a piston-like structure which pushes the pollen into the tip of the keel. The downward movement of the keel, resulting from leverage exerted by insect visitors results in the extrusion of a fine thread of pollen through the apical pore of the keel. The tip of the stigma, also protruding through this pore, is exposed to pollen already on the insect's body. Fracture of a stigmatic membrane, necessary before successful pollination can take place, seems also to be accomplished at this time. Upon release of pressure upon the keel, the flower parts return to their normal positions.

Birdsfoot trefoil has apparently been cultivated in Europe to a limited extent for approximately two hundred years. MacDonald (41) cites evidence that it was known as an agricultural crop in England prior to 1744. This same author indicates that the plant was introduced into

Australia and New Zealand in 1864. Probably it has been incidentally introduced onto the American continent many times. The earliest record which I have seen is 1876.

The agricultural value of birdsfoot trefoil has been under extensive investigation by experiment stations for the past 5–10 years. It is cultivated to a limited extent in New York, the midwest, and on the west coast. It is possible that it may become a major pasture legume within the next decade. McKee (46) comments that birdsfoot trefoil will flourish in situations unfavorable to alfalfa and clover, and makes good growth in late summer. MacDonald (41) concludes that this plant may have "distinct possibilities for hay and pasture production on poor soils, and under dry conditions where other legumes will not flourish . . ." Birdsfoot trefoil is currently recommended in Iowa for use on hilly pasture land in the southern part of the state where other legumes fail.

LOTUS MAJOR Scop. Big Trefoil, Wetland Trefoil (*Lotus uliginosus* Schkuhr, *L. major* Smith). (Plate II, Figs. 5, 6)

Similar to *Lotus corniculatus,* differing as follows: perennial from creeping scaly rhizomes; leaflets somewhat more strongly nerved than in *L. corniculatus;* calyx teeth divergent in bud; flowers 8–12 in a cluster.

This plant is widely distributed in Europe, North Africa, and western Asia — perhaps originally indigenous in only a limited portion of this area. It is now introduced and established to a limited extent in Australia, New Zealand, and the United States. It is currently grown experimentally at various argricultural colleges in the north-central states but is not naturalized. Gams (23) states that in Europe the plant grows in wet, open areas, dry or wet woodlands, low lands, usually in acid soil.

The name of this species has been subject to controversy. The epithet *Lotus major* originated with Scopoli (*Fl. Carn.* 2:86. 1772).[5] His description, however, does not clearly identify the species involved, and most American and continental European authors have preferred to use a later name, *Lotus uliginosus* Schkuhr (*Handb.* 2:412. 1804).

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[5] Scopoli's treatment of *Lotus major* is as follows:

936. *Lotus* major.

Lotus floribus umbellatis; siliquis pendulis; caule erecto. *Hall.* Enum. p. 571. n. 2. Loti corniculati major species. *I Bauh.* Hist. II. p. 355.

DIAGN. Folia lanceolate, Bracteae pariter lanceolatae. Filamenta alterna breviora, apice non dilatata.

Habitat iuxta vias in siccis; sub finem M. maii florens. Bractearum figura potuit distinguere Lotum Maritimum, a Tetragonolobo, quare ergo non et Lotum hunc a fequenti?

Many English writers have called the plant *Lotus major*, but have attributed it to Smith (*Engl. Fl.* 3:313. 1825).

Lotus major Smith is manifestly untenable. If conspecific with *L. major* Scop., it was superfluous when published; if not representing the same species, it is a later homonym. The choice between *L. major* Scop. and *L. uliginosus* Schkuhr rests primarily upon a decision as to the identity of the former. As interpretations of Scopoli's description are conflicting, some writers believing it to refer to one of the forms of *L. corniculatus* and others believing it to be based upon the same species as *L. uliginosus* Schkuhr, typification can perhaps be best carried out thru examination of his citations (see above cited footnote). This has recently been done by Robinson (60). He states his conclusions as follows:

> If we examine Bauhin's work we find the plants now known as *L. corniculatus* and *L. major* both described and also illustrated. There can be no doubt that the illustration accompanying 'Loti corniculati major species' refers to L. major Sm. = L. uliginosus Schk. It differs from that accompanying the = L. corniculatus in having more numerous and smaller flowers (despite the text which speaks of 'flores . . . in orbe conjesti, majiores') and the drawing shows in one case 8 fruits per head, and in another case 7 fruits per head, numbers which . . . are unusual in *L. corniculatus* but common in *L. major*. . . . Haller refers to the plant thus: '. . . Calyx difformis, laciniis perangustis, inferioribus rectis, et sibi proprioribus' The recurved or spreading calyx teeth are an important distinction between L. major and L. corniculatus.

Despite his weak description, Scopoli appears to have had a fairly accurate concept of the distinctions between *Lotus corniculatus* and his *L. major* (= *L. uliginosus* Schkuhr). It is not clear why, having pointed this out, Robinson proceeds to cite the species as *Lotus major* Scop. sec. Smith.

LOTUS PURSHIANUS Clements and Clements (*Hosackia americana* (Nutt.) Piper; *Lotus americanus* (Nutt.) Bisch., non Vell.; *Lotus sericeus* Pursh, non Moench) Prairie Trefoil (Plate II, Fig. 7)

> Plants annual, pubescent or glabrate. Leaves short-petioled or subsessile, trifoliolate, the terminal leaflet short-stalked; blades elliptic to ovate. Peduncles axillary, short, subtended by a trifoliate blade and usually bearing a leaflike unifoliate bract. Flowers solitary or occasionally two together. Calyx 6–7 mm. long, the teeth longer than the tube, equalling or slightly exceeding the corolla. Petals yellowish-white, the standard streaked with red. Pod oblong, 2–4 cm. in length, glabrous.

Lotus purshianus is native to western North America and extends eastward approximately to the Mississippi River. Before destruction of the prairies it was probably established further east, e.g. it has been recorded (on the basis primarily of nineteenth century collections) from Wisconsin, Illinois, and Indiana.

The prairie trefoil may be found in prairie remnants, in waste or unused ground, and along roadside and railroad right-of-ways.

Although this plant has, at various times, gone under nine different names, three generic names (*Lotus, Hosackia,* and *Acmispon*) in combination with the above cited specific epithets, it has most frequently been called *Lotus americanus* (Nutt.) Bisch. or *Hosackia americana* (Nutt.) Piper. Reasons for discarding the generic name *Hosackia* have previously been given. The specific epithet *americanus* cannot be used in the genus *Lotus* because the appropriate combination *L. americanus* (Nutt.) Bisch., 1839, is a later homonym of *L. americanus* Velloza, 1825. An earlier name, *L. sericeus* Pursh, 1814, is illegitimate for the same reason (*L. sericeus*, Moench 1802). One is forced to turn to *Lotus purshianus* of Clements and Clements, 1914. Unfortunately the validity of this name may also be open to question. Clements and Clements employ the name in a key to two species of *Lotus.* They cite no author nor name-bringing synonym, and provide no description other than statements made in the key. Presumably they obtained their specific epithet from Bentham's *Hosackia purshiana* (Lindl. *Bot. Reg.* 15:1257. 1829), but as no formal combination was made, their *Lotus purshianus* must be considered as a new name. Does a diagnosis in a key constitute valid publication? The International Rules of Botanical Nomenclature (8) give no specific answer, but since the diagnosis is sufficient to identify the plant, I am accepting it as valid.

If one recognizes the genus *Hosackia* (as some authors may prefer to do) the correct name is *Hosackia americana* (Nutt.) Piper. Nuttal described this plant in the genus *Trigonella* (*Gen.* 2:120. 1818), and there is no barrier to subsequent transfer of the specific name to *Hosackia.*

In the eastern portion of its range, *Lotus purshianus* is quite distinctive and has no close relatives. In the west, however, it is quite variable and blends with various related entities which are considered species by some authors and varieties by others. The proper classification of the western forms of (or related to) this species is not considered in the present study.

LOTUS TENUIS Kit. (*Lotus corniculatus* var. *tenuifolius* L.) Slender Birdsfoot Trefoil. Narrow-leaved Birdsfoot Trefoil (Plate II, Fig. 4)

> Similar to *L. corniculatus* but differing as follows: leaflets linear to lanceolate, less than half as broad as long; flowers 10–13 mm. in length; standard not broader than wide.

This species is native to Europe and adjacent Africa. It has become naturalized in a few places in the United States, e.g., New York, Oregon, Georgia, and Ohio (Adams County). Along with *Lotus corniculatus,* it is currently under experimental cultivation at a number of agricultural institutions.

Lotus tenuis appears to tolerate poorly drained or saline soils better than *L. corniculatus.*

The relationship of *Lotus tenuis* to *L. corniculatus* is discussed under the latter species.

TRIFOLIEAE

Annual or perennial herbs, a few subshrubby. Leaflets three, toothed or serrate. Stipules conspicuous, usually broad, membranous, and fused with petiole base. Flowers in axillary (commonly head — or spikelike) racemes, occasionally in 2–3 flowered clusters. Stamens diadelphous; anthers all similar. Pod 1–several seeded, usually indehiscent.

The Trifolieae can usually be easily recognized by the trifoliate leaves with finely toothed leaflets. The leaflet number appears to be consistent throughout the tribe with the exception of a European species of *Trifolium* (*T. lupinaster*) which has 5–7 leaflets. Aberrant leaves with a greater number of leaflets are occasionally found in other species — e.g., "four-leaf" clovers.

This tribe includes some 450–500 species in the genera *Trifolium, Trigonella, Melilotus, Medicago,* and *Parochetus.* With the exception of *Trifolium,* possessing species in both Europe and North America, most of the members of the Trifolieae appear to have originated in southern Europe, and adjacent Africa and Asia.

Schulz (62) divides the Trifolieae into two tribes on the basis of position of the seeds in the pod. This segregation does not appear to have gained acceptance. The genus *Ononis* is included in the Trifolieae by some authors.

KEY TO GENERA (PLATE III)

1. Flowers in long, slender racemes; pod indehiscent, with a coriaceous pericarp; seed usually solitary (Fig. 4). *MELILOTUS* (page 459)
1. Flowers in short, spikelike racemes, heads, or 2–3 flowered clusters; pods various, commonly several-seeded (Figs. 2, 8, 10).
   2. Pods membranous, usually concealed by the persistent perianth; flowers commonly capitate (Figs. 1, 2). *TRIFOLIUM* (page 461)
   2. Pod thick, not concealed by perianth; flowers usually in spikelike racemes, sometimes subcapitate (Figs. 7, 8). *MEDICAGO* (page 451)

KEY TO GENERA—VEGETATIVE CHARACTERS (PLATE III)

1. Stipules narrowly subulate, bristle-like (in our species); leaves pinnately trifoliate; leaflets toothed both at apex and along sides (Fig. 3). *MELILOTUS* (page 459)

1. Stipules lanceolate to ovate, frequently membranous; leaves and leaflets various (Figs. 5, 6).
   2. Leaves palmately trifoliate (Fig. 5). *TRIFOLIUM* (page 461)
   2. Leaves pinnately trifoliate (Figs. 6, 9).
      3. Plants low, prostrate or ascending; stipules entire, ovate, fused to petiole base for about half of their length; stems rounded (Fig. 6). *TRIFOLIUM* (*T. dubium* and *procumbens*)
      3. Plants not possessing the above combination of characters; if similar in appearance to the above, with lanceolate, commonly toothed or lacerate stipules fused to petiole for less than half of their length, and square stems (Fig. 7). *MEDICAGO* (page 451)

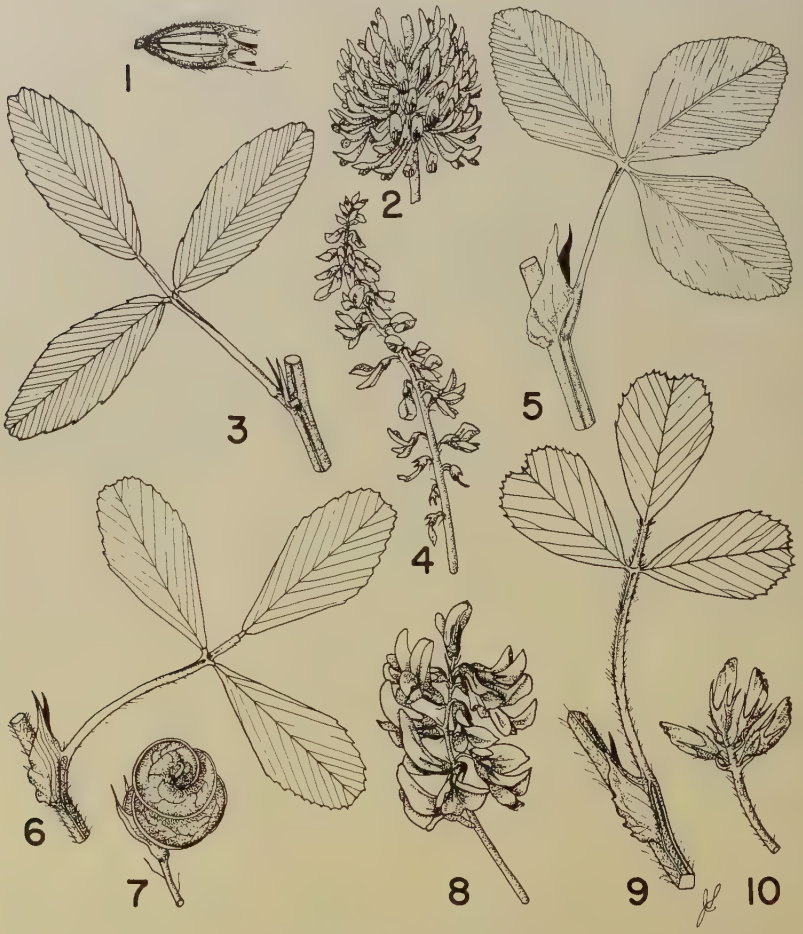

PLATE III, TRIFOLIEAE

Trifolium pratense, 1. Fruiting calyx, showing position of pod x 3. 2. Head x ⅔. *Melilotus officinalis*, 3. Leaf and stipule x 1½. 4. Branch of inflorescence x 1. *Trifolium hybridum*, 5. Leaf and stipule x 1½. *Trifolium procumbens*, 6. Leaf and stipule x 2. *Medicago sativa*, 7. Pod x 2½. 8. Spike x 1. *Medicago lupulina*, 9. Leaf and stipule x 2. *Medicago hispida*, 10. Flower cluster x 2.

MEDICAGO L.

Herbs or rarely low shrubs. Leaves pinnately trifoliate. Flowers usually yellow or purplish, in axillary, spikelike or capitate racemes, occasionally reduced to 1–3 in a cluster. Petals not adnate to stamen column. Stigma oblique. Pod not enclosed by perianth, usually spirally rolled up or bent, one–several seeded, sometimes spiny.

Medicago includes approximately fifty species native to Eurasia and adjacent Africa. Most of the annual species are limited to the Mediterranean region. The perennials are more widely distributed, particularly to the north and east. Several species, through the activities of man, are now found in nearly all temperate regions of the world.

The basic chromosome number in this genus appears to be 8. Most of the species have $2n$ numbers[6] of 16 or 32.

LITERATURE

ARMSTRONG AND WHITE, (2), alfalfa, seed setting
BRINK AND COOPER, (7), alfalfa, pollination
CARLSON, (12), alfalfa, seed setting
———, (13), alfalfa, seed setting
FRYER, (22), chromosome number
GAMS, (23, 1248–75), European spp.
HAYEK, (26, 834–43), Balkan spp.
HAYWARD, (27, 309–38), alfalfa morphology
ISELY, (34), seed characters
MCKEE, (45), bur-clovers
———, (46, 714–18), cultivated spp.
——— AND RICKER, (47), annual species
OAKLEY AND GARVER, (50), *Medicago falcata*
RYDBERG, (61, 460–61), central U. S. spp.
SENN, (64, 204–11), chromosome numbers
TRABUT, (67), origin of alfalfa
TYSDAL, (68), alfalfa, seed setting
——— AND KIESSELBACH, (69), alfalfa
VANSELL AND TODD, (70), alfalfa, pollination
WESTOVER, (71), alfalfa varieties.

KEY TO SPECIES (PLATE IV)

1. Flowers 7–11 mm. long; plants perennial, erect, ascending, or sometimes decumbent; stipules lanceolate to subulate, commonly fused to petiole for less than one-fourth of length (Figs. 4, 5).
   2. Pod spirally twisted; flowers various in hue, predominately violet; leaflets usually obovate to oblanceolate; plants common (Figs. 5, 6). *MEDICAGO SATIVA* (page 455)
   2. Pod straight or falcately curved; flowers yellow; leaflets oblong; plants rare (Figs. 7, 8). *M. FALCATA* (page 451)
1. Flowers 3–5 mm. long; plants usually annual, decumbent; stipules ovate to lanceolate, usually toothed or lacerate, commonly fused to petiole for about one-third of length (Figs. 1, 2).
   3. Pods black, one-seeded, not spiny; stipules toothed or entire (Figs. 1, 3). *M. LUPULINA* (page 454)
   3. Pods brownish, spirally coiled and several-seeded, usually spiny; stipules lacerately divided (Figs. 9, 10). *M. HISPIDA* (page 453)

MEDICAGO FALCATA L. Yellow-flowered alfalfa (Plate IV, Figs. 7, 8)

Similar to *Medicago sativa,* differing primarily as follows: plants prostrate to ascending, sparsely hairy to grey-pubescent. Leaflets narrowly oblong, 3–6 times as long as wide. Flowers 7–11 mm. long, yellow. Pod about 1 cm. long, straight to falcately curved, with a slender stylar beak.

[6] As employed here and elsewhere in this paper, $2n$ signifies the somatic chromosome number in contrast to the n or gametic compliment.

Medicago falcata is native in eastern Europe and western Asia, probably extending considerably further north in Siberia than *M. sativa*. It also occurs in central Europe, but it is likely that this is outside of its original range. The plant has been under observation for some years at experiment stations in the central United States and elsewhere and has become established to a slight extent. It is tolerant of a wide range of soil and climatic conditions and is more cold resistant than *M. sativa*.

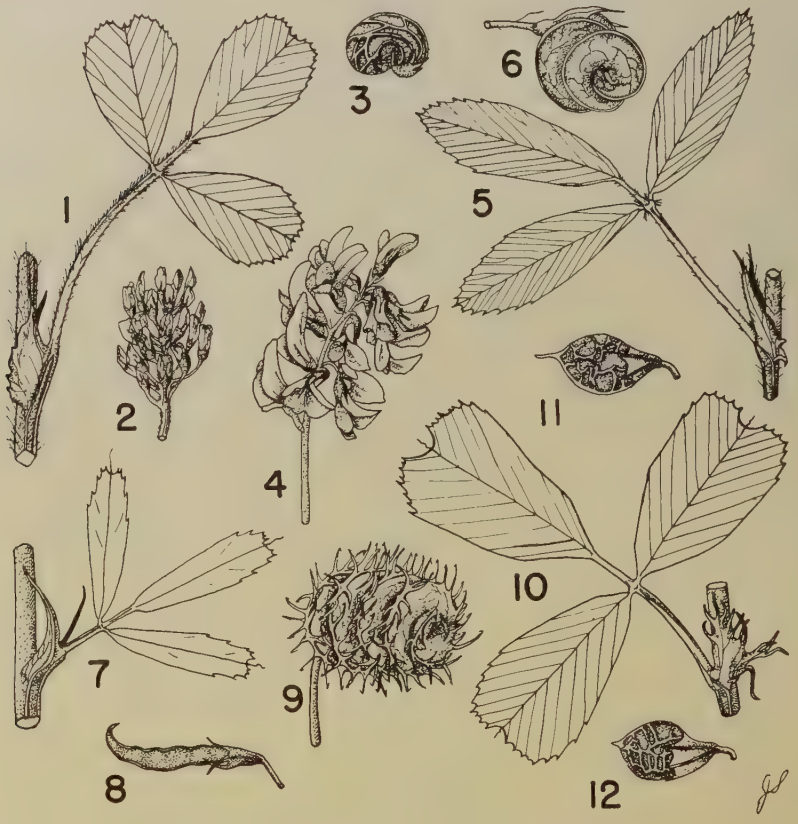

PLATE IV, *MEDICAGO* AND *MELILOTUS*

Medicago lupulina, 1. Leaf and stipule x 2. 2. Flowering head x 4. 3. Pod x 6. *Medicago sativa*, 4. Spike x 1. 5. Leaf and stipule x 1½. 6. Pod x 2½. *Medicago falcata*, 7. Leaf and stipule x 2. 8. Pod x 2. *Medicago hispida*, 9. Pod x 2½. 10. Leaf and stipule x 1½. *Melilotus albus*, 11. Pod x 4. *Melilotus officinalis*, 12. Pod x 4.

Chromosome numbers, $2n = 16$ and 32 have been reported for *Medicago falcata* [Fryer, (22); Senn, (64)].

Numerous strains of yellow alfalfa have been introduced into the United States by the U. S. Department of Agriculture. The interest in this species has been mainly due to its value as breeding material. It has been hoped that the introduction of genetic material of *M. falcata* into commercial varieties of *Medicago sativa* would facilitate the development of cold resistant strains. The potentialities of such a breeding program are illustrated by the various variegated alfalfas, presumably hybrids between these two species, which are less subject to winter killing than most other varieties. The inter-relationships of *Medicago falcata* and *M. sativa* are discussed under the latter.

MEDICAGO HISPIDA Gaertn, (Incl. *M. denticulata* Willd., *M. apiculata* Willd., *M. confinis* Koch) Bur clover, California bur clover. (Plate IV, Figs. 9, 10)

Annual. Stem prostrate or ascending, much branched at base, glabrate or puberulent. Leaflets cuneate-obovate or obcordate, glabrate or pubescent beneath; terminal leaflet borne on a stalk 2–4 mm. long. Stipules lacerate, the incisions extending more than halfway to base (stipules on basal leaves may be less divided). Racemes axillary, 3–5 (1–8) flowered. Corolla yellow, 2.5–4 mm. long. Fruits brown, 4–6 mm. wide, several seeded, 2–5 times spirally twisted; margin with two rows of hooked spines which are separated by a distinct ridge, or spines reduced or absent. Seeds yellowish, kidney-bean shaped.

Medicago hispida is native to Mediterranean Europe and adjacent Asia. It is also found throughout much of Western Asia (possibly native) and Central Europe (probably not native). It has now been introduced and established in nearly all warm-temperate agricultural regions of the world. In the United States it occurs throughout the southern and Pacific states — most abundantly on the west coast — and may be found sporadically further north. It occurs in southern Missouri.

Bur clover is generally a ruderal along roadsides, railroads, and on waste ground. It grows either as an annual or winter annual and flowers in the early spring months.

Medicago hispida is variable in respect to certain fruit characters, i.e., the size, number of spirals, and length of the spines. These variants have been divergently interpreted as varieties, subspecies, or as separate species. Further study is necessary to elucidate their relationship. Some of these forms are tabulated below.

1. Fruit 4–6 mm. wide; spirals 1½–3.
   2. Spines rudimentary or absent — var. *confinis* (Koch) Burnat
   2. Spines present.
      3. Spines very short. — var. *apiculata* (Willd.) Urban
      3. Spines longer, their length equaling radius of spirals. — var. *denticulata* (Willd.) Urban (the common form)
1. Fruit 7–10 mm. wide; spirals 4–6.
   4. Spines rudimentary. — var. *terebellum* (Willd.) Urban
   4. Spines present, their length equaling radius of turns. — var. *nigra* (Willd.) Burnat

Another bur clover, *Medicago arabica* (L.) All. (*see* list of excluded species), which is common in the southern United States, is frequently confused with *M. hispida*. These plants differ as follows: *Medicago arabica*: leaflets averaging the broader of the two, frequently with a reddish-brown spot or blotch, the terminal one only slightly longer stalked than laterals; stipules lacerately toothed, but teeth usually not extending halfway to middle of stipule; pod spines generally curved throughout entire length, the rows separated by a narrow furrow on edge of pod (this furrow is frequently difficult to see on pods flattened on herbarium sheets). *Medicago hispida*: leaflets slightly narrower, not dark blotched, the terminal one with a stalk 2–4 mm. in length; stipules lacerate with incisions extending more than half-way to base; pod spines usually straight and hooked at the end, the rows on pod separated by a ridge.

Senn (64) tabulates determinations of $2n$ chromosome numbers of both 14 and 16 for this species. Fryer (22), who found a somatic number of 14 in four varieties studied, comments that chromosome size is variable in different varieties, and that some possess satellites while others do not.

Bur clover has been in this country at least since the early part of the last century. Doubtless it has been incidentally introduced many times. The plant is highly regarded for early spring pasturage in California and range lands in the southwest. Its strong points are (1) its ability to reseed itself and maintain a stand from year to year, (2) its nutrient value, supplementing grass pasturage, and (3) its availability in early spring months. In the establishment of new permanent pasture areas it is sometimes seeded in combination with grasses, particularly Bermuda grass. It is also used for hay and as a cover crop.

MEDICAGO LUPULINA L. Black medic, Yellow trefoil (Plate IV, Figs. 1–3)

Plant usually annual or biennial, glabrate or hairy. Stems much branched at base, decumbent, ascending at tips, 4-angled. Leaflets wedge-shaped to elliptic. Stipules ovate-lanceolate, entire or toothed, usually adnate to petiole for ¼–⅓ of their length — those of basal leaves may be fused for more than ½ of length. Racemes arising from upper leaf axils, pedunculate, closely 10–40 flowered, ovoid, becoming short-cylindrical in fruit. Flowers 2–3 mm. long, yellow, the corolla deciduous in fruit. Pod 1-seeded, reniform, reticulate, black at maturity. Seeds oblong-ovoid, yellow-green, usually with a papilla-like projection on hilum side.

Black medic is naturalized in nearly all temperate regions of the world. Undoubtedly it is native in Eurasia; it is to be found in nearly all of Europe, adjacent Africa, and much of Asia. There is, however, little evidence to indicate the extent of its range within this area before dis-

semination by man. It is now established throughout most of the United States, occurring in all of the north-central states, although it is uncommon in the western half of the western group (Kansas, Nebraska, the Dakotas). It is usually found as a weed or incidental plant about human habitations, along roadsides, and in waste places. It may be found in bloom throughout the summer.

Medicago lupulina is variable in regard to habit, pubescence, flower size, and duration. The greater number of these variants are probably caused by minor genetic factors or are ecologically induced. Various varietal and form epithets which have been applied to them most likely have little significance. The common, sparsely hairy annual variety has been designated var. *vulgaris* Koch; a perennial strain may be termed var. *cupaniana* (Guss.) Boiss.

Senn (64) quotes several authors who report 16 somatic chromosomes for *M. lupulina* and one who reports 32.

Black medic has been cultivated in England since the middle of the seventeenth century. Its employment in continental Europe is more recent. It is common in Hawaii and, according to Hosaka and Ripperton (33) is highly regarded for forage. Black medic has been in the United States since the colonial days. Although employed to a slight extent for winter pasturage and as a cover crop, it has never achieved importance in this country.

MEDICAGO SATIVA L. Alfalfa (Plate IV, Figs. 4–6)

Plants perennial, deep rooted from a subligneous crown. Stems numerous, ascending or erect, smooth or finely hairy. Leaflets apically toothed, glabrate or pubescent, those of the lower leaves obovate, the upper blades narrowly oblong or oblanceolate. Stipules lanceolate, slightly toothed, basally fused to petiole, to 2.0 cm. in length. Racemes axillary, spikelike, 10–20 (30) flowered. Flowers 7–11 mm. long, violet or varicolored (purplish to dull yellowish-green or brown). Pods several-seeded, sparsely hairy, spirally twisted with 1½–3 turns, 4–5 mm. wide. Seeds dull yellow, kidney-bean shaped or irregularly ovoid, twisted, or angular.

Alfalfa was probably originally native to the region east and northeast of the Mediterranean, i.e. Turkey, eastern Siberia, Iran, Iraq, and possibly Afghanistan. This is somewhat conjectural since long continued distribution of the plant by man makes determination of its original range difficult. Alfalfa now occurs in nearly all temperate regions of the world. It may be found throughout the United States. It is very abundant in the north-central states, both in cultivation and as an escape along roadsides and in waste areas. It blooms in early summer.

In the strict sense, *Medicago sativa* represents a species with large (8–11 mm.), blue-violet flowers, an erect habit, and strongly coiled pods. Many of the cultivated alfalfas, however, are widely variable as regards flower color and size, habit, and degree of coiling of the pods; it is generally asumed that such strains possess genetic material, not only of typical *M. sativa,* but of one or several of its immediate relatives.

The most likely additional progenitor of cultivated alfalfa is *M. falcata,* so-called yellow alfalfa. This species is native to the same general region as *M. sativa* but appears to range further north in Siberia. *M. sativa* and *M. falcata* are distinct in regard to several morphological characters but are interfertile. Possibly there was once little overlapping between the two species. However, with the initiation of agricultural employment of alfalfa, this species was carried far beyond its natural boundaries by man. Extensive hybridization between it and *M. falcata* could well have been the natural result. Perhaps, inasfar as the cultivated strains are concerned, one can say that *M. falcata* and *M. sativa* as such have been bred out of existence. This may not be true of the wild species in their native habitats which, because of differential climatic requirements, are probably not likely to completely overrun one another.

The names *Medicago media* Pers., and *M. varia* Martyn., are applied applied to alfalfa-like plants growing wild east of the Mediterranean and in adjacent Siberia. These "species" are intermediate between *M. sativa* and *M. falcata* and in large part probably represent a natural hybrid population. The variegated alfalfas of commerce are morphologically representative of this *media-varia* complex. They (the cultivated forms) appear to contain (1) strains derived by selection from wild hybrid populations, (2) strains derived as above and extensively backcrossed with *M. sativa,* (3) synthetic strains resulting from experimental hybridization between *M. sativa* and *falcata.* In the southern Ukraine, there are alfalfa-like plants, *M. microcarpa* Urban and *caerulea* Less. and Leb. which are distinguished by the small size of their flowers (5–7 mm. long) and pods; they are also variable as to flower color. Probably they too should be referred to the *M. sativa-falcata* complex.

As might be expected, *Medicago sativa* and its allies are variously classified. Some authors treat the group as four to six separate species employing the above indicated names. Gams (23), on the other hand, reduces them all (including *M. falcata*) to subspecific rank under *M. sativa.* In the present paper, *M. sativa* is delimited in the broad sense except that *M. falcata* is excluded. Cultivated plant populations morphologically representing *M. media, varia, et al.* are considered to fall within the limits of *Medicago sativa.* In their native habitat it is possible that these variants may be broken into sufficiently disjunct population groups to warrant their segregation into subspecies or varieties — the present author is in no position to offer an opinion. However, subdivision of *M. sativa* as it occurs in the United States does not appear practical. Our

different kinds of alfalfa are dependent upon man for their continued existence as distinct entities. They are in no sense independent plant populations. Escaped and ruderal alfalfa populations probably soon blend together.

Numerous authors have reported a $2n$ chromosome number of 32 for alfalfa. The chromosomes are small and no satellites are present.

Pollination in alfalfa, and other species of *Medicago* is affected by a so-called explosive or tripping mechanism within the flower. When the flower opens, the stamen column and pistil are retained within the keel but are under considerable elastic tension. When a nectar-seeking insect lights on the flower, the downward pressure releases certain keel and wing processes which hold the stamens in place, and the column abruptly snaps forward striking either the base of the standard or the body of the insect. This process, commonly known as tripping, facilitates successful pollination. Not only is pollen released and cross pollination rendered possible through the medium of the insect visitor, but rupture of a stigmatic membrane is accomplished when the stigma strikes the standard or the insect. The stigma is not receptive until this membrane is broken. Because of the frequent failure of alfalfa to produce a good seed set, the mechanism of pollination and subsequent seed development has been studied in some detail by a number of workers, e.g., Armstrong and White (2), Brink and Cooper (7), Carlson (12, 13), Tysdal (68), Vansell and Todd (70). Conclusions drawn by these students are not entirely in agreement although it may be safe to conclude that, (1) tripping and seed set are usually strongly correlated under field conditions, (2) most tripping is caused by insects.

Alfalfa has been cultivated for at least 2500 years, longer than any other forage crop. It was apparently first grown by the early Persian or contiguous civilizations. According to DeCandolle (17), it was introduced from Persia into Greece in the fifth century B. C. From Greece the plant and its culture spread successively into Italy, Spain, France and thence fanned out over central Europe. It reached England in the seventeenth century. It did not, however, assume an important role in European agriculture until the last few hundred years; this is generally attributed to a lack of knowledge of inoculation requirements. Alfalfa was probably first brought to the western hemisphere by the Spanish who introduced it into Mexico and South America. It came into the American colonies from England during the early part of the eighteenth century, but assumed no important place in early colonial agriculture. The successful establishment of alfalfa as a economic crop in North America took place a hundred years later during the gold rush at which time seeds were brought to California from Chile. It rapidly became recognized as a valuable forage crop, but for the first thirty–forty years after this introduction was grown almost exclusively in the Pacific and western states. Although seed production is still primarily in the west, the area of utilization now includes the north-central and eastern United

States. It is seldom grown in the southeastern states, the limiting factor being a high summer temperature–high humidity combination. Elsewhere in the world, alfalfa is a major forage crop in nearly all temperate or subtemperate regions in which relatively dry summer conditions are available.

Alfalfa is the most important forage crop in the United States, both from the standpoint of total acreage, and tonnage of hay produced. It is grown for hay and pasturage, and is perhaps the most valuable legume in soil improvement rotations. It also is used in silage and in making feed concentrates.

The alfalfas grown in the north-central States consist of several strains which differ as to origin and physiological characteristics. They may be roughly classified in four groups: (1) Common. These are purple-flowered alfalfas, for the most part descended from stock introduced during the last century. Some secondary selection into specific varieties has been made, but in large part the "common" group passes as just alfalfa. (2) Turkistan. Turkistan alfalfas are purple-flowered strains introduced from Russian Turkistan by the U.S. Department of Agriculture about 1900. They tend to be sparser in growth and less erect than the common groups. The varieties Hardistan and Orestan are Turkistan alfalfas. (3) Variegated. These include varieties which possess varicolored flowers, and which (although many perhaps only remotely so) are of hybrid origin. The varieties are diverse as to growth characteristics. In general they are more cold resistant than common alfalfas. Several of our most important varieties belong to this group, among them Grimm, Canadian variegated, Cossack, Baltic, Ladak, and Hardigan. (4) Nonhardy. The nonhardy alfalfas, the so-called Peruvian and Arabian varieties, are little employed in the north-central states. They are best adapted to southern regions with a long growing season.

Among the varieties above enumerated, Grimm is perhaps the best known. This variety had its origin on the Minnesota farm of a Wendelin Grimm, who for many years during the middle part of the last century produced his own seed and selected for winter hardiness. Until the recent development of new varieties, Grimm alfalfa has been the principal standby of farmers in the northern United States, and is still much grown. Cossack alfalfa, introduced from Siberia by the U. S. Department of Agriculture, is quite winter resistant, but like Grimm is susceptible to bacterial wilt. Ladak is descended from an introduction from India. It is less susceptible to wilt than many other varieties. Hardistan, developed by selection in Nebraska, is also relatively wilt resistant. It has unusual ability to maintain a stand over a period of years. Baltic and Hardigan are improved strains somewhat similar to Grimm. Ranger and Buffalo are two promising new varieties. Ranger is a synthetic variety developed in Nebraska from several Turkistan and variegated strains. Buffalo, a Kansas product, represents selections from the common group.

Detailed information concerning alfalfa varieties is given by Westover (71), and Tysdal and Keisselbach (69).

MELILOTUS ADANS.[7] SWEETCLOVER

Annual or biennial herbs. Leaves pinnately trifoliolate. Stipules commonly subulate. Flowers in elongate racemes, erect in bud, reflexed after flowering.

Calyx short, campanulate. Corolla yellow or white, free from stamen tube and deciduous after anthesis. Stigma terminal. Pod not concealed by perianth, usually 1-seeded, compressed-ovoid, indehiscent or nearly so.

Melilotus is a genus of about twenty species, native to Mediterranean Europe and Africa, and Western Asia. Several members of the genus, particularly *M. albus, officinalis,* and *indicus* are now widely distributed in temperate regions over the entire world. In this hemisphere, Anderson (1) has reported *M. albus* and *officinalis* to be sparingly established as far north as Alaska; at the other extreme, Burkhart (11) treats five species which are naturalized in Argentina. All species of *Melilotus* reported by Senn (64) have a $2n$ chromosome number of 16.

LITERATURE

Coe, (14), cultivated spp.
Gams, (23, 1236–48), European spp.
Hayek, (26, 843–46), Balkan spp.
McKee, (46, 718–19), cultivated spp.
Pieters and Kephart, (58), cultivated spp.
Rydberg, (61, 461), central U. S. spp.
Schulz, (62), monograph
Sears et. al., (63), cultivated spp.
Senn, (64, 211–13), chromosome numbers
Willard, (72), cultivated spp.

KEY TO SPECIES (PLATE IV)

1. Flowers white, 4–5 mm. long; pod reticulate-nerved (Fig. 11).
MELILOTUS ALBUS (page 459)
1. Flowers yellow, 4.5–7 mm. long; pods usually cross-ribbed (Fig. 12).
M. OFFICINALIS (page 461)

MELILOTUS ALBUS Desr. White Sweetclover (Plate IV, Fig. 11)

Plants biennial or annual. Stems erect, sparsely hairy, 1–2 m. tall. Leaflets obovate to oblong, toothed along sides and at apex. Stipules narrowly awl-shaped. Flowers white, 4–5 mm. long. Calyx 1.5–2 mm. long; teeth deltoid or subulate. Standard slightly exceeding keel and wings. Pods ovoid, reticulate-nerved.

[7] Author citations in recent manuals indicate that there is divergence of opinion as to whom the genus *Melilotus* should be attributed. The name *Melilotus* was used by several pre-Linnaean authors, as well as by Linnaeus himself. However, Linnaeus (Sp. 2:765. 1753), employed it in an accessory sense under *Trifolium* without characterization of the portion of the genus delimited. Hill also (*Fl. Brit.* 379. 1760) included his Meliloti under *Trifolium* subordinate to a polynomial heading, *Meliloti leguminibus nudis polyspermis.* Adanson (*Fam.* 2:322. 1762) treated *Melitotus* as a genus, and gave a brief diagnosis in outline form. He cited only pre-Linnaean authorities for the name (i.e., no reference to Hill), hence, his *Melilotus* is a new name, inasfar as priority is concerned, not a combination.

Most American authors have declined *Melilotus* as feminine. Properly, it should be masculine [Briquet, (9); section 14], thus *Melilotus albus* rather than *M. alba.*

Seeds greenish-yellow, compressed-ovoid; hilar notch inconspicuous.

The original home of white sweetclover cannot be determined with any degree of certainty but was probably Asia Minor and adjacent western Asia. The plant now occurs throughout most of Europe, western Asia, Australia, and temperate North and South America. It is abundant in all of the north-central states both in cultivation and as a common roadside and waste ground weed.

Flower color of herbarium specimens of *Melilotus albus* and *M. officinalis* is frequently indistinguishable. Specific identification can usually be made on the basis of mature pods (see descriptions) but it is desirable to examine several pods as those of *M. officinalis* sometimes appear netted. If mature pods are not present, differential flower size may, in many cases, serve as a basis of identification. Also, the pistil of *M. officinalis* is distinctly stipitate, while that of *M. albus,* although narrowed at the base, is scarcely stalked. Conclusions drawn in regard to the comparative lengths of the petals are not dependable when observations are made on dried flowers. There are no distinctive vegetative distinctions between these species, although the upper leaflets of *M. albus* appear to average narrower than those of *M. officinalis.*

In common with other species of *Melilotus,* white sweetclover is ordinarily cross pollinated; however, (in which it differs from yellow sweetclover) at least some strains are self fertile and will set seed in absence of pollinating agents.

The $2n$ chromosome number of *Melilotus albus* is 16. Fryer (22) reports that two large satellites are present, whereas there are none in *M. indicus* and *officinalis.*

White sweetclover has been cultivated in Europe and Western Asia to a limited extent for many years but has never achieved any importance. It became sporadically established on the eastern coast of the American continent during the eighteenth century and gradually moved westward as the country was opened to agriculture. It was generally considered a weed. Its employment as a crop has, for the most part, been within the last thirty years.

The merit of sweetclover lies primarily in its ability to succeed in dry, sterile soils where other legumes (alfalfa, red clover) will not persist. In the southeastern United States it plays an important role, both as a wild and cultivated plant, in the initial stages of reclamation of impoverished soils and serves as a source of hay at the same time. In the north-central states, sweetclover is valuable as a honey plant; it is employed (commonly in rotations) for hay, green manure, and pasture. The chief drawback to the use of sweetclover as an animal food is that it contains a material, coumarin, which under certain conditions breaks down into a toxic substance. The development of coumarin-free varieties has recently been initiated.

White sweetclover is usually slightly higher yielding than yellow

sweetclover and is frequently advantageous for hay or pasture. Yellow sweetclover is better at establishing a stand under unfavorable, dry conditions, is earlier maturing, and a better seed producer. It is particularly recommended for soil improvement purposes.

Most white sweetclover carries no special variety designation. Named varieties grown in the north-central states include Hubam, Grundy County, and Evergreen. Hubam is an annual strain developed in Iowa. It produces a high proportion of top and a relatively small amount of root growth as compared with the biennial forms. Grundy County sweetclover, (Illinois) is a relatively uniform, early maturing variety and a good seed producer. Evergreen, an Ohio production, is said to be late maturing, to have high yield and disease resistance; its seed production potentialities leave much to be desired because of uneven ripening.

MELILOTUS OFFICINALIS (L.) Lam. Yellow Sweetclover (Plate IV, Fig. 12)

Similar to *Melilotus albus*, differing as follows: flowers yellow, 4.5–7 mm. long; standard and wings subequal. Calyx basally rounded or slightly gibbous. Pod conspicuously cross-ribbed.

Like white sweetclover, yellow sweetclover is common throughout the north-central states as a naturalized element of the wild flora, as a cultivated crop, and as an escape. Generalizations as to world distribution, history, and agricultural employment discussed under *M. albus* also apply to yellow sweetclover.

Madrid is a fine-stemmed, leafy variety of yellow sweetclover. It is slightly later maturing than the standard yellow variety and possesses especially vigorous first year growth.

TRIFOLIUM L. CLOVER

Annual, biennial or perennial herbs. Leaves trifoliolate (in our species) the lower petioled, upper usually subsessile; leaflets pinnately or palmately disposed. Stipules conspicuous, foliaceous or membranous, partially fused to petiole. Inflorescence racemose, spicate or capitate, axillary or terminal, sometimes conspicuously involucrate. Calyx commonly two-lipped. Corolla white to reddish or yellow; petals adherent to stamen column, usually persistent after anthesis. Pod short, enclosed within calyx and corolla, scarcely dehiscent, 1–4 seeded.

Trifolium, including some 250–300 species, is the principal genus of the Trifolieae. Its representatives are native to two widely separated areas of the earth: (1) Europe and adjacent Asia and Africa, particularly the Mediterranean region, (2) western North America, three species extending east of the Mississippi river. The larger number of species are Eurasian. Due to the activities of man, about a dozen European species are now widespread over the entire temperate and subtemperate

world and a number of others have become sparingly established in regions far from their native homes. The common clovers of the north-central states are European species. Several of them are widely grown as agricultural crops, and are also established as a part of the naturalized plant cover. Some species may be considered weeds.

The principal agricultural value of clovers is forage, i.e., hay, pasturage, and silage. Clovers are also important honey plants. White clover is commonly planted in lawns.

Chromosome numbers in this genus mostly range from $n = 7$ to 24. The majority of species have 8 or multiples of this figure. Senn (64) suggests that 8 is the basic number and that species with 7 chromosomes are derived hypoploids. The number 7 occurs in all species of the section *Chronosemium,* and in scattered species elsewhere in the genus.

LITERATURE

Deam, (16, 595–97), Indiana spp.
Fassett, (18, 36–38), Wisconsin spp.
Fernald, (19), varieties of red clover
———, (20), varieties of alsike clover
Gams, (23, 1275–351), European spp.
Hayek, (26, 846–74), Balkan spp.
Hollowell, (29), white clover
———, (30), crimson clover
———, (31), Ladino white clover
———, (32), Persian clover
Isely, (35), seed characters
Jepson, (36, 286–312), California spp.
Klages, (38, 522–23, 541–49), cultivated spp.
Lojacono, (39), North American species
———, (40), key to species
McDermott, (44), North American spp.
McKee, (46, 722–24), cultivated spp.
Pieters, (55), red clover
———, (56), nomenclature of red clover
———, (57), alsike clover
Rydberg, (61, 458–60), central U. S. spp.
Senn, (64, 213–18), chromosome numbers

KEY TO SPECIES (PLATES V, VI, AND VII)[8]

1. Flowers yellow.
   2. Leaves pinnately trifoliate, the terminal leaflet stalked; flower heads usually 0.5–1 cm. in length (Figs. 11, 14).
      3. Flower heads 15–40 flowered; standard distinctly striate; petioles mostly longer than leaflets (Figs. 13, 14, 15).
         TRIFOLIUM PROCUMBENS (page 473)
      3. Flower heads 5–10 flowered; standard scarcely striate; petioles mostly shorter than leaflets (Figs. 10, 11, 12). *T. DUBIUM* (page 467)
   2. Leaves palmately trifoliate, the terminal leaflet not stalked; flower heads usually 1–1.5 cm. in length (Fig. 9). *T. AGRARIUM* (page 464)
1. Flowers not yellow.
   4. Flowers distinctly stalked (pedicels exceeding 2 mm. in length), usually recurved in fruit (Fig. 6, 7).
      5. Calyx lobes narrowly lanceolate or bristle-like, more than two times longer than the tube (Fig. 23).
         6. Plants stoloniferous; leaves all long petioled and arising from ground level (either from central crowns or stolons) except for short-petioled, opposite pairs subtending flower heads; scapes usually thicker than stolons; plants essentially glabrous (Fig. 20).
            T. STOLONIFERUM (page 477)
         6. Plants with numerous erect or ascending stems; leaves becoming progressively shorter petioled up the stem; plants glabrous or hairy (Fig. 22). *T. REFLEXUM* (page 474)
      5. Calyx lobes deltoid or lanceolate, up two times as long as tube (Figs. 1, 4).
         7. Calyx lobes 3-nerved; plants moderately pubescent, uncommon, open woodlands, southern (Fig. 16).
            T. CAROLINIANUM (page 467)

[8] Figures on these plates are numbered consecutively.

7. Calyx lobes 1-nerved; plants glabrous, abundant, cultivated and escaped (Figs. 1, 4).
8. Stems procumbent, rooting at nodes, heads on long scapes arising from ground level; flowers usually whitish or pale pink; calyx lobes 0.8–1.1 times as long as tube (Figs. 4, 8).
T. REPENS (page 476)
8. Stems ascending or erect; heads on short peduncles at apex of stem; flowers usually pinkish; calyx lobes 1.2–2.0 times as long as tube (Figs. 1, 2). *T. HYBRIDUM* (page 469)
4. Flowers subsessile (pedicels not exceeding 1 mm), frequently not recurved in fruit (Figs. 30, 31).
9. Heads narrowly ovoid or cylindrical; flowers scarlet or white (Fig. 24).
10. Corolla whitish, shorter than calyx lobes; leaflets narrowly oblong (Figs. 25, 26). *T. ARVENSE* (page 466)
10. Corolla scarlet, exceeding calyx; leaflets obovate (Figs. 27, 28). *T. INCARNATUM* (page 469)
9. Heads spherical or wider than long; flowers red to pink-purple (Figs. 31, 34).
11. Flowering heads 2–4 cm. in width, not enlarged in fruit; fruiting calyces not bladdery-inflated (Fig. 31).
12. Leaflets obovate to elliptic; plants pubescent, common (Fig. 29). *T. PRATENSE* (page 471)
12. Leaflets narrowly elliptic to oblong; plants glabrous, local in eastern South Dakota (Fig. 18).
T. BECKWITHII (page 466)
11. Flowering heads up to 1.2 cm. in width, much enlarged in fruit; fruiting calyces bladdery inflated (Figs. 32, 34).
T. RESUPINATUM (page 476)

KEY TO SPECIES—VEGETATIVE CHARACTERS (PLATES V, VI, VII)

1. Terminal leaflet longer stalked than lateral ones; plants low; leaflets commonly less than 1 cm. in length (Figs. 11, 14).
2. Petioles mostly shorter than leaflets (Fig. 11).
TRIFOLIUM DUBIUM (page 467)
2. Petioles mostly longer than leaflets (Fig. 14).
T. PROCUMBENS (page 473)
1. Terminal leaflet not longer stalked than lateral ones; plants various (Fig. 3).
3. Plants stoloniferous, essentially glabrous; stems usually rooting at nodes; leaves long petioled (Figs. 8, 20).
4. Plants abundant about human habitations, pastures, and fields; stipules whitish-membranous, usually less than 1 cm. in length (Figs. 5, 8).
T. REPENS (page 476)
4. Plants rare; stipules foliaceous, usually 1–2 cm. in length (Figs. 19, 20).
T. STOLONIFERUM (page 477)
3. Plants not stoloniferous, hairy, or glabrous; stems not rooting at nodes; upper stem leaves usually shorter petioled than basal ones (Figs. 2, 22).
5. Stems glabrous.
6. Stipules small, free portion about 1–1.5 mm. in width, usually with 3 unbranched nerves; leaflets finely sharp-denticulate (Fig. 33).
T. RESUPINATUM (page 476)
6. Stipules 3–10 mm. in width, usually with several branched nerves; leaf margin finely sinuate to denticulate (Figs. 3, 21).
7. Leaflets elliptic to oblong, strongly-nerved; plants perennial from a thick, semi-woody crown, local in eastern South Dakota (Fig. 18).
T. BECKWITHII (page 466)
7. Leaflets obovate to ovate, not strongly nerved; plants annual or perennial, without a semi-woody crown, widely distributed (Figs. 3, 21).
8. Stipules ovate-lanceolate to narrowly lanceolate, 3–8 times as long as wide, frequently long attenuate at tip; plants common in cultivation and disturbed areas (Fig. 3).
T. HYBRIDUM (page 469)

8. Stipules ovate to ovate-lanceolate, mostly not more than two and one-half times as long as wide, acute or abruptly acuminate at tip; plants primarily in undisturbed areas (Fig. 21).
T. REFLEXUM (page 474)

5. Stems pubescent.
9. Leaflets 3–6 times as long as wide, hairy; stipules bristle-tipped (Fig. 26). *T. ARVENSE* (page 466)
9. Leaflets usually 1–2 times as long as wide, glabrous or hairy—if 2–3 times as long as wide, glabrous; stipules various (Figs. 21, 29).
10. Secondary veins in leaflets essentially unbranched; leaflets usually 1.5–2.5 times as long as wide (Fig. 9).
T. AGRARIUM (page 464)
10. Secondary veins in leaflets branched near margin; leaflets usually 1–1.5 times as long as wide (Figs. 21, 29).
11. Most of stipules fused to petioles for one-half to three-fourths of their length (Figs. 27, 29).
12. Stipules bristle-tipped; plant abundant in cultiva- in north-central states (Fig. 29).
T. PRATENSE (page 471)
12. Stipules not bristle-tipped, usually darkened at apex; plant cultivated in south, uncommon in north-central states (Fig. 27).
T. INCARNATUM (page 469)
11. Most of stipules fused to petioles for less than one-half of their length (Figs. 17, 21).
13. Stems erect or ascending, usually 1.5–3 mm. in diameter; leaflets usually exceeding 1 cm. in length (Fig. 21).
T. REFLEXUM (page 474)
13. Stems decumbent at base, usually about 1 mm. in diameter; leaflets usually less than 1 cm. in length (Fig. 17).
T. CAROLINIANUM (page 467)

TRIFOLIUM AGRARIUM L. Hop Clover (Plate V, Fig. 9)

Annual or winter annual. Stems ascending or erect, finely pubescent. Leaflets ovate to narrowly rhombic-ovate, the terminal one not longer stalked than laterals; veins mostly unbranched. Lower stipules narrowly oblong, only apex free from petiole; upper stipules lanceolate, one- to two-thirds of length fused to petiole. Spikes strongly peduncled, ovoid, to 1.3 cm. in width and 1.8 cm. in length, closely flowered. Flowers short-pedicelled, recurved after anthesis. Calyx 2-lipped. Corolla yellow, 4–5 mm. long; standard exceeding other petals, slightly dentate laterally, striate-nerved. Style approaching pod in length. Seeds dull greenish-yellow, terminally notched.

Trifolium agrarium, native to Europe and adjacent Asia, has been in the new world since at least the first of the nineteenth century. It is locally common in the north-eastern and central United States extending as far west as Minnesota, Iowa and Missouri. It is usually found in waste places, along roadsides and railroad embankments.

See *Trifolium procumbens* for a discussion of nomenclature of yellow-flowered species of *Trifolium.*

PLATE V, *TRIFOLIUM*

Trifolium hybridum, 1. Calyx x 4. 2. Habit x ⅓. 3. Leaf and stipule x 1½. *Trifolium repens*, 4. Calyx x4. 5. Stipule x 2. 6. Flower x 3. 7. Head x–1. 8. Habit x ⅓. *Trifolium agrarium*, 9. Leaf and stipule x 1½. *Trifolium dubium*, 10. Head x 2. 11. Leaf and stipule x 2. 12. Flower x 4. *Trifolium procumbens*, 13. Head x 2. 14. Leaf and stipule x 2. 15. Flower x 4.

TRIFOLIUM ARVENSE L. Rabbit-foot clover. (Plate VI, Figs. 24–26)

Annual or winter annual. Stems erect, sparingly branched, commonly villous-pubescent. Leaflets usually narrow, oblong to linear-lanceolate, silky-pubescent. Free portion of stipules subulate or bristle-like, pilose. Inflorescences on axillary or terminal peduncles, densely flowered, at first subcapitate, elongating into cylindrical spikes. Flowers 10–30, 3–4 mm. long, sessile. Calyx silky-pilose; teeth bristle-like, exceeding tube and corolla. Petals white or pale pink, inconspicuous. Seeds ovoid, obscurely notched, lemon-yellow.

Rabbit-foot clover, presumably originally native to Europe, now occurs throughout that continent (excepting the northernmost portions), over much of adjacent Asia, North Africa, and is adventive in North America, Hawaii, and scattered areas elsewhere. It has been in North America since the colonial days and is to be found throughout most of the eastern United States. It is common in the southeastern states where it is regarded as a weed. It is occasionally or locally abundant in the eastern portion of the north-central states west to Missouri, Iowa, and southern Minnesota.

Trifolium arvense favors areas with a light, sandy soil, frequently occurring in sterile situations where other legumes fail.

European literature divides *Trifolium arvense* into numerous subspecific groups. Among the more significant of these are: (1) Var. *typicum* Beck.: plant spreading-villous; calyx $\frac{1}{3}$–$\frac{1}{2}$ longer than the corolla. (2) Var. *gracile* (Thuill.) Ser.: plants glabrate. (3) Var. *longisetum* Boiss.: calyx teeth very long, more than twice exceeding corolla. Most of our plants are closely pubescent and appear to fall into var. *typicum*. Some specimens, only inconspicuously strigose, perhaps approach var. *gracile*. Leaflet width is variable, ranging from obovate to narrowly obovate or oblong (most common) to linear.

Senn (64) reports the $2n$ chromosome number of *T. arvense* to be 14.

TRIFOLIUM BECKWITHII Brewer (Plate VI, Fig. 18)

Plant perennial from a stout crown, glabrous. Stems clustered, ascending to erect, usually low. Leaflets palmately trifoliolate, elliptic to oblong, strongly nerved. Stipules membranous, ovate to lanceolate. Peduncles terminal, usually solitary. Heads globose, 2–3 cm. in diameter. Flowers short pediceled, reflexed in age. Corolla 1–1.3 cm. long, reddish-purple.

This clover is native to the Rocky Mountains west to the Pacific states. It has been reported from South Dakota by Britton and Brown (10), Rydberg (61) and Over (53). I have seen five specimens of the plant from South Dakota, all from the extreme eastern portion of the state (four from Brookings County, and one from Codington County).

It has not been clear whether this species is native in South Dakota, or whether it has been introduced from farther west and has become established. The following information kindly given me by the Soil Conservation Service [Atkins, (3)] suggests that it may be native: "Last July we found this species in a wet meadow or slough around a small lake northwest of Watertown,[9] South Dakota . . . it was growing in a heavy sod of switchgrass, big bluestem, western wheatgrass, and green needlegrass. . . ."

TRIFOLIUM CAROLINIANUM Michx. (Plate VI, Figs. 16, 17)

Plants perennial. Stems decumbent or ascending, pubescent. Leaflets palmately disposed, cuneate-obovate. Stipules ovate-lanceolate, commonly sparsely toothed. Flower heads long-pedunculate, exceeding leaves. Flowers pedicelled. Calyx sparsely pilose; teeth exceeding tube, broadly lanceolate, subfoliaceous, 3-nerved, frequently net-veined. Corolla purple, 5–7 mm. long, equaling or slightly exceeding calyx; wings toothed. Pod 2–3 seeded.

Trifolium carolinianum is a native species. It centers in the southern United States, from the Gulf and Atlantic coastal plains north to Virginia, west to southeastern Kansas and Texas. It is generally found in poor soil in relatively undisturbed open areas.

TRIFOLIUM DUBIUM Sibth. Little hop clover, Suckling clover. (Plate V, Figs. 10–12)

Plants annual or winter annual. Stems low, decumbent or ascending, puberulent. Leaves pinnately trifoliolate, very short petioled. Leaflets obovate. Stipules ovate, acute. Flowers in loose, 3–12 flowered heads, reflexed after anthesis. Calyx two-lipped, lower teeth lanceolate. Corolla approximately 2.5–3 mm. in length, drying brownish, persistent; standard weakly striate. Pods 1–2 seeded. Seeds elliptic, shiny yellow when mature.

This species is native to the Eurasian continent. It probably became established in the United States during the last century. At the present time it is most common in the southeastern United States and the northern Pacific states. It occurs in the eastern group of the north-central states but is infrequent. It usually inhabits dry roadsides, path borders, or waste places.

A somatic chromosome number of 14 has been reported for *Trifolium filiforme,* and an *n* number of 14 for *T. minus* (64). As used by some authors, these names are synonymous, at least in part, with *Trifolium dubium.*

Little hop clover is grown to a limited extent in the southern states. It is most commonly planted in mixtures with white clover. It is capable

[9] Codington County.

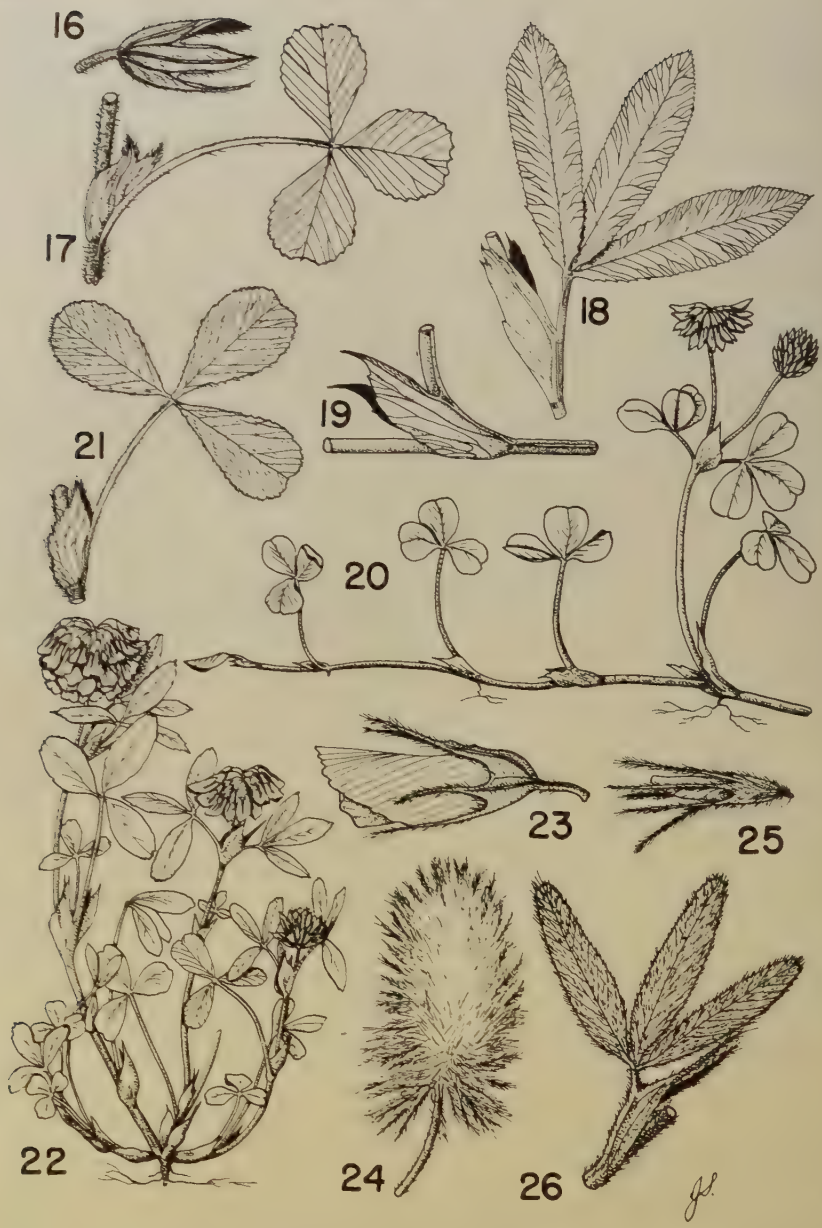

PLATE VI, *TRIFOLIUM* (cont.)

Trifolium carolinianum, 16. Calyx x 4. 17. Leaf and stipule x 2¼. *Trifolium beckwithii*, 18. Leaf and stipule x 1. *Trifolium stoloniferum*, 19. Stipule x 2. 20. Habit x ⅓. *Trifolium reflexum*, 21. Leaf and stipule x 1. 22. Habit x ½. 23. Flower x 3. *Trifolium arvense*, 24. Flowering spike x 1½. 25. Flower x 4. 26. Leaf and stipule x 2.

of producing a stand under rather adverse soil conditions, and is said to be valuable for early spring pasturage.

TRIFOLIUM HYBRIDUM L. Alsike Clover (Plate V, Figs. 1–3)

Plants perennial. Stems smooth, 3–5 mm. in diameter, ascending or erect. Leaves glabrous; leaflets palmately disposed, obovate. Stipules clasping, foliaceous, ovate-lanceolate to oblong, acute. Heads globose, borne on peduncles which arise from upper leaf axils. Flowers numerous, slender pediceled, reflexed in age. Calyx lobes 1.2–2 times exceeding tube, not membranous-widened at base. Corolla 5–8 mm. in length, pinkish or white. Standard exceeding the other petals. Pod 2–3 seeded. Seed heart-shaped, smooth, light green to greenish black.

Like all of our cultivated clovers, alsike is European in origin. It is probably native in eastern Europe, but is now naturalized over much of the continent and England. It is also naturalized in much of the United States. It is most common in the north-central, eastern and Pacific northwest areas. Alsike clover may be found in fields, along roadsides, and not infrequently penetrates open woodlands, particularly in wet soil or along streams.

Trifolium hybridum is commonly considered to consist of two varieties or subspecies, *T. hybridum fistulosum* (Gilib.) Rouy and *T. hybridum elegans* (Savi.) Boiss. Both of these two varieties are found in the United States. The former represents the cultivated forms and differs from the latter primarily in size, having larger leaves and flower heads; the peduncles are also usually longer and the plants are more erect. It is possible that var. *elegans* represents the ancestral wild form and that var. *fistulosum* has been derived from it by selection.

Senn (64) reports a $2n$ chromosome number of 16 for *Trifolium hybridum.*

Alsike clover was first cultivated in Sweden, approximately 1750. Its agricultural employment in this country began about a hundred years later. Alsike is grown primarily as a substitute for red clover, in wet or sour soil. It cannot compete with red clover under favorable soil conditions. It is employed in essentially the same parts of the country as red clover, the north-central, eastern, and Pacific northwest regions.

TRIFOLIUM INCARNATUM L. Crimson clover (Plate VII, Figs. 27, 28)

Annual or winter annual. Stem erect, pubescent. Leaflets palmate, obovate, pubescent or glabrate. Stipules conspicuous, ovate to oblong; lanceolate, frequently purplish-tipped. Flowers sessile, in peduncled, cylindrical spikes. Calyx 8–10 mm. long, silky-pilose, with setaceous teeth which exceed the tube. Corolla scarlet, slightly exceeding calyx. Seeds larger than those of other species, ovoid, shiny yellow.

Crimson clover is native to Mediterranean Europe. It is naturalized in the southern United States where it is cultivated, and is occasionally adventive elsewhere. It has been collected several times in most of the north-central states but is probably established only in southern Mis-

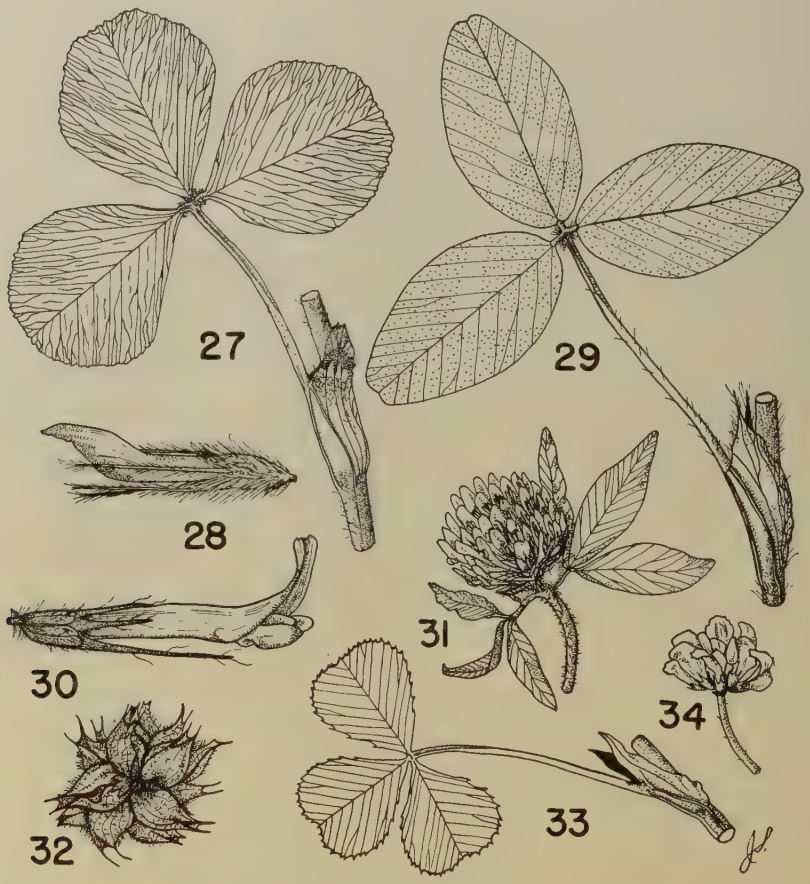

PLATE VII, *TRIFOLIUM* (cont.)

Trifolium incarnatum, 27. Leaf and stipule x 1. 28. Flower x 3. *Trifolium pratense*, 29. Leaf and stipule x 1. 30. Flower x 3. 31. Head x ¾. *Trifolium resupinatum*, 32. Fruiting head x 1½. 33. Leaf and stipule x 2. 34. Flowering head x 1½.

souri. Crimson clover blooms in May and June, and at this time of the year is extremely conspicuous in regions where it is common.

There are two varieties or races of *Trifolium incarnatum*. The typical form, sometimes called var. *sativum* Ducommun is the one described

above. Var. *molinerii* (Balb.) DC. is a lower plant, with short, loose spikes of small yellowish-white flowers. It rarely occurs in the United States.

Senn (64) reports $2n$ chromosome numbers of 16 and 14 for crimson clover.

The agricultural value of crimson clover was first recognized in Europe during the latter part of the eighteenth century. Cultivation was initiated in France, Switzerland, and Germany. The earliest record of the plant on the American continent appears to be 1818. In subsequent years it received a moderate amount of attention as an ornamental. However, it was not until the latter part of the nineteenth century that it was employed on any considerable scale as an agricultural crop.

Crimson clover is cultivated primarily on the southeastern coastal plain, from New Jersey south to south-central Georgia, Alabama, and Mississippi, and north to southern Kentucky. It is also grown to a limited extent in the Pacific northwest. It is planted as a winter annual and its northern usefulness is limited by its susceptibility to winter killing. The plant is utilized for soil improvement, for early pasture and for hay. It is tolerant of poor soil conditions, but may be adversely affected by hot, dry conditions, in either spring or fall.

TRIFOLIUM PRATENSE L. Red Clover (Plate VII, Figs. 29–31)

Plants biennial or perennial. Stem basally decumbent; main branches erect, pubescent or glabrate. Leaflets short-stalked, obovate to elliptic, pubescent on both sides or glabrate above, often with a darkened or reddish, transverse line or spot. Stipules conspicuous, to 2 cm. in length, fused to petiole for more than one-half of length, oblong-lanceolate, bristle-tipped. Flower heads globular, short-pedunculate, surrounded by an involucre of broadly stipulate, reduced leaves. Flowers 30–80 per head, sessile, not reflexed after anthesis. Calyx approximately 6 mm. in length, sparsely pilose; teeth equaling tube, narrowly lanceolate. Corolla 13–15 mm. long, reddish to reddish-purple, rarely white; keel and wings long clawed, much exceeded by the elliptic standard. Pods 1–2 seeded. Seed ovoid, with a distinct lateral lobe, yellowish and purple blotched.

Red clover is European in origin. It is now found in nearly every portion of the temperate world where agriculture is practiced. It is naturalized to some extent throughout the United States, but is most common in the northern half of the country, and is abundant in all of the north-central states. Red clover occurs, exclusive of cultivated areas, along roadsides and about farmsteads.

Trifolium pratense, a highly variable species, has been divided into numerous subspecific categories. The utility of such divisions is questionable inasmuch as treatments by various authors differ widely, and as many of the subspecific units probably have little biological significance. Gams' (23) synopsis of this species seems more satisfactory

than that proposed by other authors. A modified, summary of his treatment is presented below. He catalogues several subvarieties and forms under each of the varieties listed:

1. Plants with weak, appressed pubescence; stipules hairy primarily on nerves.
   2. Stems ascending to erect, 4–7 dm. long; leaves and heads large.
      var. *sativum* (Crome) Schreb. (the common cultivated form in Europe)
   2. Stems decumbent to ascending, lower than above; leaves and heads moderate in size.
      var. *spontaneum* Wilk.
      (the common wild form in Europe, distinctly smaller in stature than cultivated varieties.)
1. Plants with conspicuous rough pubescence (frequently becoming glabrate in age); stipules commonly hairy over entire surface.
   3. Plants vigorous, ascending to erect; leaflets 3–4 cm. long and 1–1.5 cm. wide; flowers red, rarely white.
      var. *americanum* Harz
      (a south European race; much North American cultivated material falls here.)
   3. Plants decumbent to ascending; leaflets smaller than above; flowers frequently yellowish-white.
      4. Heads small, mostly less than 2 cm. across; upper leaflets narrow; stipules with long ciliate tips. var. *maritimum* Zabel
      4. Heads large, 2–3 cm. wide; leaflets broad; stipules not ciliate-tipped.
         var. *frigidum* Gaudin
         (an alpine race)

Several authors have reported a $2n$ chromosome number of 14 for red clover (64).

Red clover is self sterile. Cross pollination is accomplished by various Hymenoptera and Lepidoptera. Bumble bees and honey bees are most important. Downward pressure on the wings and keel exerted by a visiting insect will cause the stigma and stamens to protrude from the keel. Upon release of this pressure, the flower parts return to their original positions; they are capable of reacting in the same manner to a succession of visitors. This manner of pollination is characteristic of most species of *Trifolium* and contrasts with the tripping apparatus of alfalfa, and the piston-like mechanism of birdsfoot trefoil.

Red clover has been under cultivation for several hundred years. Fifteenth century records indicate its use as an agricultural crop in the general region now occupied by Holland and Belgium. Its value as natural forage was undoubtedly recognized for some time prior to this date and actual cultivation may have begun considerably earlier. Its utilization reached England by approximately 1650. The introduction of red clover into the American colonies probably occurred before 1750. It rapidly became important in the new world agriculture.

Next to alfalfa, red clover is the most important forage legume in the United States. It is of maximum value in the north-central and northeastern states, succeeding best in well drained, limed soils. Red clover is frequently planted in legume – row crop – small grain rotations, being employed for hay, soil improvement, and pasturage. It is seeded alone or in conjunction with other forage crops, particularly timothy. Seed production is centered primarily in the north-central states and the Pacific northwest.

Cultivated red clover strains fall into two general groups, the so-

called medium red (double cut) clover and mammoth red (single cut) clover. The medium clover flowers about two weeks earlier than the mammoth clover and is slightly lower and less pubescent. A few named varieties of red clover have been developed during the past ten years but seed stocks are still somewhat limited. Among these, Emerson and Kenland have been developed in Iowa and Kentucky respectively. Midland and Cumberland are composite, synthetic strains. Midland is best adapted for the northern portion and Cumberland for the southern portion of the red clover growing area of the central United States.

TRIFOLIUM PROCUMBENS L. Hop clover, Large hop clover, Mignonette clover (Plate V, Figs. 13–15).

Plants annual or winter annual. Stem decument or ascending, rounded, finely appressed-hairy to villous. Leaves pinnately trifoliolate; petioles mostly longer than leaflet blades; leaflets obovate, sparsely pubescent or glabrous. Stipules ovate, about one-half of length fused to petiole. Flowers 20–40, in globular heads. Calyx two-lipped, the lower teeth filiform, frequently curved. Corolla 3.0–3.5 mm. long, yellow, brownish-persistent in fruit; standard conspicuously striate. Pod 1-seeded, short-stipitate. Seeds shiny yellow, narrowly elliptic, notched near one end.

Trifolium procumbens is native to Europe, and occurs throughout that continent with the exception of northern Scandinavia and the mountain masses. It is introduced in north Africa, eastern Asia (possibly native), the Americas, and the Hawaiian Islands. In the United States it is most common in the southeastern and Pacific regions. It is occasional or locally abundant in the north-central states west to eastern South Dakota and Kansas. It is found primarily in disturbed but uncultivated areas. Gams (23) referring to its occurrence in Europe, says that *T. procumbens* generally occurs in alkaline soil.

Trifolium procumbens, T. dubium, and *Medicago lupulina* are superficially similar in appearance and are frequently confused. The distinctions between the two clovers are indicated in the keys to *Trifolium.* They are contrasted with *Medicago lupulina* below:

	Trifolium dubium and *procumbens*	*Medicago lupulina*
Stems	Rounded.	Angled or square.
Stipules	Entire, fused to petiole for about half of length.	Toothed or entire, fused to petiole for less than half of length.
Flower heads	Spherical or broader than wide, loosely flowered.	Usually ovoid, tightly flowered.
Flowers	Reflexed after anthesis; petals persistent.	Not reflexed; petals deciduous.
Fruit	Brown, enclosed within persistent perianth.	Black, not enclosed.

The names employed in the present paper for the hop clovers (*Trifolium procumbens* L., *T. dubium* Sibth., and *T. agrarium* L.) are those generally used by other American authors. The nomenclature employed in European studies is diverse, and, for the most part, not in accord with that used in this country.[10] These varied interpretations have originated because of difficulties in typifying the Linnaean names, *Trifolium procumbens, filiforme,* and *agrarium.* Linnaeus probably did not have a clear concept of these closely related species; in any case, his species can scarcely be interpreted in terms of currently accepted specific lines. This latter fact is evidenced by incongruities between his diagnoses, specimens, and references cited [for further details see Briquet, (8)]. A further complicating circumstance is the fact that Linnaeus' definition of at least two of these species appears to have changed between the first edition of his *Species Plantarum,* published in 1753, and the second edition of his *Flora Suecica,* two years later.

In considering the nomenclature of these plants, one finds it necessary to choose one of three alternatives, viz.: (1) a re-examination of the problems involved in the typification of the Linnaean names, (2) the abandonment of these names as *nomen dubia* — Article 63 of the *International Rules of Botanical Nomenclature* (9) — and taking up of the next available names, (3) the arbitrary employment of the names used by most American authors. The first alternative appears unsatisfactory since Appendix I of the *International Rules of Botanical Nomenclature* pertaining to the determination of types has never been elaborated; the present confusion is in large part due to the fact that several viewpoints, if perhaps not equally admissible, are at least consistent with the rules of nomenclature. The writer is inclined to favor the second alternative which has already been suggested by Briquet (8). However, the seventh International Botanical Congress will be meeting in the near future. It appears probable the action taken at that meeting in regard to typification may simplify the determination of the proper names of these clovers. For the present, then, the names of the hop clovers are employed in the usual American sense.

Senn (64) reports a $2n$ chromosome number of 14 for *Trifolium procumbens.*

Large hop clover is of limited value in the southeastern and Pacific states for forage and soil improvement. Hosaka and Ripperton (33) report that it is valuable for grazing in moist uplands in Hawaii.

TRIFOLIUM REFLEXUM L. Buffalo Clover (Plate VI, Figs. 21–23)

Plants annual, hairy or glabrous. Stems clustered, ascending. Leaflets oblong to broadly obovate, sessile. Stipules ovate to lanceolate, foliaceous, to 2 mm. in length. Flower heads globular, 3–4 cm. in diameter, 20–30 flowered. Flowers 7–11 mm. in length;

[10] Names used by European authors for these species include—in addition to *Trifolium procumbens, dubium,* and *agrarium—T. campestre* Schreb., *T. micranthum* Viv., *T. filiforme* L., *T. minus* Sm., and *T. aureum* Poll. The same names used by different authors frequently refer to different species.

pedicels slender, 4–10 mm. long, recurved after anthesis. Calyx pubescent or glabrous, frequently with ciliate teeth and a glabrous tube; teeth 2–3 times exceeding tube, narrowly subulate, about 4 mm. in length. Standard reddish (occasionally white), wings and keel white or pink; corolla persistent after flowering, becoming brownish-papery. Pod 2–4 seeded. Seed dull yellowish, finely warty.

Buffalo clover is native to the central and eastern United States, primarily south of the glacial limits. In the north-central states it extends west to eastern Kansas and Nebraska, north to northern Iowa, Illinois, and central Indiana. The plant is most frequently an inhabitant of dry, open woods, commonly on acid soil.

Trifolium reflexum is typically pubescent, but sparsely hairy or glabrate forms are not uncommon. Such plants are commonly called var. *glabrum* Loj. However, there appears to be no clear line between hairy and glabrous forms.

An attempt was made to obtain a rough numerical notion of pubescence differences exhibited by this species. Five arbitrary pubescence classes were established as follows: I. Calyx and stem closely hairy. II. Calyx tube sparsely hairy, teeth hairy; stem hairy. III. Calyx tube glabrous, teeth ciliate; stem moderately hairy. IV. Calyx glabrous; stem thinly hairy. V. Calyx and stem entirely glabrous. Among 217 herbarium collections examined, the number of specimens falling into each group was: I, 43; II, 33; III, 61; IV, 22; V, 58.

This tabulation seems to indicate a progressive intergradation in regard to degree of pubescence. On the basis of specimen identifications, variety *glabrum* Loj. as interpreted by some botanists appears to include only group V, by others it apparently includes IV, and sometimes part of III. No definite correlation between geographical distribution and degree of pubescence could be established although there was an indication that a higher proportion of the glabrate forms were western. It is to be doubted if pubescence variation has any more biological significance than does leaflet shape or flower color — characters which are also variable in this species. However, botanists may feel, that since the completely glabrate form is conspicuously different in appearance than the pubescent phase, that nomenclatorial recognition is desirable. If so, it deserves no more than *forma* status, therefore:

TRIFOLIUM REFLEXUM forma *GLABRUM* (Loj.) Isely stat. nov. *Trifolium reflexum* var. *glabrum* Lojacono Nuov. Giorn. Bot. Ital. 15:150. 1883. Calyx and stem entirely glabrous (equivalent to Group V above). Intergrading with plants which have ciliate calyces and sparsely hairy stems.

Glabrous forms of *Trifolium reflexum* are commonly confused with *T. stoloniferum*. Differences are pointed out in the key, and briefly discussed under *T. stoloniferum*. *Trifolium reflexum* var. *virginicum* (Small) McDermott, an Appalachian endemic, has not been observed in the present study.

TRIFOLIUM REPENS L. White clover, Dutch clover, Ladino clover (Plate V, Figs. 4–8)

Plants perennial. Stems glabrous, decumbent, rooting at nodes, 2.0–2.5 (occasionally 3) mm. in diameter. Leaves glabrous, borne on long, erect petioles; leaflets obovate to obcordate, equally stalked. Stipules whitish-membranous or papery, frequently violet-streaked. Peduncles leafless, radical, 1–2.5 dm. long. Heads globular, 40–70 flowered. Flowers 6–9 mm. long, pediceled, reflexed after anthesis. Calyx teeth approximating tube or shorter, broadened at base with a membranous border. Corolla white or pinkish. Pod 2–3 seeded. Seeds yellow, heart-shaped.

White clover, a native of northern Europe, is now widely distributed throughout the temperate and subtropical world; it is perhaps the most cosmopolitan of all legumes. It is abundant in the north-central states except for the more arid portions of the western Dakotas, Nebraska, and Kansas. White clover is widely planted but is also common as a naturalized species, occupying open or disturbed areas of all kinds.

White clover is largely self-sterile, hence cross pollination is a necessity. The pollination mechanism is essentially the same as that described for red clover; honey bees are the most important pollinating agents. Chromosome numbers ($2n$) of 16, 28, and 32 have been reported for white clover (64).

Cultivation of white clover is said to have begun in Holland — probably about the first of the eighteenth century. It had become established on the eastern seaboard of the United States by 1750 and moved westward with the white man. Ladino clover, originally indigenous to northern Italy, was brought to this country in 1903.

White clover is extensively employed in pasture mixtures, particularly in the north-central and northeastern United States. It has a high carrying capacity and is frequently able to reseed itself year after year. It is also used for hay and silage. It is commonly seeded in conjunction with Kentucky bluegrass for lawns.

Cultivated varieties or strains of white clover differ from one another in size. The so-called wild or English white clovers are relatively small and low. Common white or white Dutch clover, the most common cultivated form in this country, is intermediate in size. Ladino and Louisiana white clovers are relatively large.

TRIFOLIUM RESUPINATUM L. Persian Clover (Plate VII, Figs. 32–34)

Plants annual or winter annual. Stems glabrous, decumbent or ascending. Leaves, except for the lowermost, short petioled or subsessile. Leaflets obovate to oblanceolate, equally stalked, finely sharp-toothed. Stipules subulate. Peduncles axillary, unbranched, 2–3 cm. in length, slightly exceeding subtending leaves. Heads 0.5–0.9 cm. wide in flower, 1.5–2.0 cm. broad in fruit,

8–18 flowered. Flowers subsessile, 4–7 mm. long, pink-purple; petals basally twisted so that standard appears ventral. Calyx hirsute, the upper lip much inflated in fruit, forming a bristle-tipped, net-nerved papery sac. Seeds heart-shaped, shiny greenish-black to black.

Persian clover is native to southeastern Europe. It is naturalized to a limited extent in the southern United States, and occurs sporadically in the north-central states. I have seen specimens from Illinois and South Dakota; the plant is reported from Kansas (24), Missouri (54), and Wisconsin (18). In Europe, it is said to flourish on wet bottom land and to tolerate a moderate amount of salinity.

Hollowell (32) states that Persian clover is self-fertile, and self-pollinated. Senn (64) tabulates a $2n$ chromosome number of 16 for this plant.

Persian clover is a minor forage crop in the southern states. Hollowell (32) indicates that it is particularly valuable for early spring pasturage, that it has a high feed value as hay and that it may also be used for green manure. Persian clover is not as exacting in regard to soil requirements as white clover. It is possible that its employment will expand in the future.

TRIFOLIUM STOLONIFERUM Muhl. (Plate VI, Figs. 19, 20)

Plants perennial. Stems stoloniferous, frequently somewhat sinuate, rooting at nodes, glabrous or slightly hairy. Leaves (except those subtending flower heads) radical, long petioled, arising in clusters from the crowns and at intervals along the stolons. Leaflets obovate, glabrous. Stipules oblong (on radical leaves) or ovate (on scape leaves), pointed. Scapes exceeding leaves, usually thicker than stolons, bearing toward upper extremity a pair of opposite, short-petioled leaves which subtend 1–2 short, sparsely hairy peduncles. Heads and flowers essentially similar to those of *Trifolium reflexum*. Calyx glabrate, or somewhat hairy. Flowers whitish, usually tinted with lavender.

Trifolium stoloniferum is native to the north-central states. It extends from South Dakota and Missouri east to Ohio and Kentucky. It is local in its occurrence.

This species is closely related to the more widely distributed, variable *Trifolium reflexum*. Specimens of glabrate forms of *Trifolium reflexum* are commonly confused with *Trifolium stoloniferum*, particularly when material is fragmentary and the habit cannot be clearly made out. The chance of confusion is increased by botanical manuals which state that calyces of *T. stoloniferum* are pubescent in the sinuses while those of *T. reflexum* are not. This is not correct; calyx teeth of both species may, or may not be ciliate — in the sinuses or apically. The best distinguishing characters between these species involve the habit and petiole length.

EXCLUDED SPECIES

ANTHYLLIS VULNERARIA L. Kidney vetch

Kidney vetch is a widespread Eurasian member of the Loteae with yellowish clover-like heads and pinnately compound leaves. It has been reported in Iowa and North Dakota. As its seeds are frequently found in those of European grown red clover seed, it has probably been introduced into all of the north-central states. However, the plant has shown no tendency to become established.

MEDICAGO ARABICA (L.) All.

This bur clover is reported from South Dakota by Over (53). There are, however, no sheets of *M. arabica* in the Herbarium of the University of South Dakota. The only specimen of this plant from the north-central states observed is one from Lincoln, Nebraska, collected in 1909 and labeled as "cult." *M. arabica* is common in the southern United States and occasional in the southwest and California. While it has doubtless been introduced into the north-central states a number of times it probably has not become established.

MELILOTUS ALTISSIMUS Thuill.

Melilotus altissimus is a yellow flowered sweetclover which differs from *M. officinalis* in having a pubescent ovary and weakly reticulate pods. It is sparingly established in the eastern United States. A nineteenth century collection from Wisconsin is reported by Fassett (18). The plant does not now appear to occur in the north-central States.

MELILOTUS INDICUS (L.) All. Sour clover

Sour clover, native to the Mediterranean region and western Asia is common in the southwestern United States and California. It is reported from the north-central states by Rydberg (61). However, there seems to be no evidence verifying its persistence in this region.

TRIFOLIUM DEPAUPERATUM Desv.

This species was reported from Michigan by Beal (4). There is no evidence indicating its present occurrence in the north-central states.

TRIFOLIUM FUCATUM Lindl.

Reported by Beal (4) as above.

TRIFOLIUM FRAGIFERUM L. Strawberry clover

This plant has been grown experimentally on a limited scale at agricultural institutions in the north-central states. It is not cultivated in this area, and does not appear to have become naturalized.

TRIFOLIUM MEDIUM L.

This species has been reported from the north-central states several times. These reports are probably attributable to (1) the application of the name *Trifolium medium* to Mammoth red clover; (2) glabrate forms of *T. pratense* being confused with a related species.

Pieters (56) discusses the nomenclature of red clover, in detail, concluding that the name *Trifolium medium* should not be applied to any of our cultivated forms. *T. medium*, a distinct European species, is sparsely hairy or glabrate; it has narrower leaves than *T. pratense*, and narrower stipules which are not bristle-pointed at apex; the calyces are glabrous or with ciliate teeth. The true *Trifolium medium* is neither cultivated nor established in the north-central states.

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SPRING WATERFOWL MIGRATION THROUGH CLAY AND PALO ALTO COUNTIES, IOWA[1]

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Received November 16, 1950

Between March 14 and June 1, 1948, and between March 18 and June 1, 1949, approximately 650 and 600 hours, respectively, were spent observing waterfowl in Clay and Palo Alto counties, locally called the "Ruthven Area." In 1948 about 176,000 geese, ducks, and coots, representing 21 species, were estimated to be in the area, and in 1949 about 222,000, representing 23 species—an increase of 26 per cent. The lakes and marshes that were checked daily and the per cent of the total number of waterfowl observed on each were: Trumbull Lake, 10 per cent; Round Lake, 6 per cent; Mud Lake, 11 per cent; Smith's Slough, 16 per cent; Green's Slough, 5 per cent; Barringer's Slough, 45 per cent; Dewey's Pasture, 3 per cent; and Brown's Slough, Whitford's Slough, Johnson's Slough, the Oppedahl Tract, and Lost Island Lake, less than 3 per cent. Other observers—Bennett (2), Low (7), and Provost (10)—have checked the spring migration; consequently, the relative abundance of the various species can be compared for 1934, 1938, 1942, 1948, and 1949.

FIELD TECHNIQUE

The census was made by a direct count of flocks with less than 100 individuals and by an estimation of flocks with more than 100 birds. The sex ratios of the different migratory species were recorded where observations with the aid of an 8 x 56 binocular provided positive identification. The counts were made during all hours of the day from a boat, an automobile, an airplane, and certain field vantage points, but only one daily tabulation was made for each of the water areas.

POPULATIONS

Weather conditions prevailing at the time of the arrival of the first migrants were similar in 1948 and 1949. A warm, south wind with a velocity of 10 to 20 miles per hour had been blowing most of the day, and the ducks arrived during the late afternoon. In 1948 all of the lakes and marshes had been frozen since January, and there was about 2 inches of

[1] Journal Paper No. J-1858, Project No. 496, Iowa Agricultural Experiment Station, Ames, Iowa. U. S. Fish and Wildlife Service, Iowa State College, Iowa State Conservation Commission, and Wildlife Management Institute, cooperating.

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TABLE 1

COMPARATIVE LENGTH OF THE SPRING MIGRATION PERIOD FOR WATERFOWL IN CLAY AND PALO ALTO COUNTIES, IOWA

Species	Migration Period				
	1934	1938	1942	1948	1949
	(*Bennett*)	(*Low*)	(*Provost*)	(*Glover*)	(*Glover*)
Canada Goose	Apr. 19–May 5	Mar. 17–Apr. 26	Mar. 21–May 29	Mar. 16–Apr. 1	Mar. 20–May 21
White-fronted Goose	Apr. 6–Apr. 30	Mar. 26–Apr. 29	Mar. 21–May 9	Mar. 23–Apr. 9	Mar. 29–Apr. 1
Lesser Snow Goose	Mar. 19–May 2	Mar. 22–Apr. 30	Mar. 21–May 9	Mar. 19–Apr. 12	Mar. 22–Apr. 23
Blue Goose	Mar. 19–May 1	Mar. 22–May 27	Mar. 21–Apr. 28	Mar. 19–Apr. 12	Mar. 22–Apr. 23
Mallard	Mar. 15–N	Mar. 21–N	Mar. 15–N	Mar. 16–N	Mar. 20–N
Gadwall	Apr. 4–Apr. 28	Mar. 24–Aug. 12	Mar. 27–May 19	Mar. 24–SR	Mar. 20–May 26
Baldpate	Apr. 2–Apr. 28	Mar. 24–June 4	Mar. 27–June 9	Mar. 24–SR	Mar. 22–May 26
Pintail	Mar. 15–N	Mar. 21–N	Mar. 15–June 9	Mar. 18–N	Mar. 20–N
Green-winged Teal	Mar. 20–Apr. 28	Mar. 26–May 28	Mar. 26–Apr. 29	Mar. 24–Apr. 28	Mar. 22–May 3
Blue-winged Teal	Apr. 7–N	Mar. 21–N	Mar. 27–N	Mar. 24–N	Apr. 4–N
Shoveller	Mar. 23–N	Mar. 21–N	Mar. 28–N	Mar. 20–N	Mar. 22–N
Wood Duck	.....	.....	May 15–June 3	.....	Apr. 4–Apr. 28
Redhead	Mar. 20–N	Mar. 22–N	Mar. 27–N	Mar. 23–N	Mar. 25–N
Ring-necked Duck	Mar. 20–May 1	Mar. 23–May 12	Mar. 21–May 20	Mar. 19–Apr. 14	Mar. 20–May 10
Canvas-back	Mar. 15–N	Mar. 22–N	Mar. 29–N	Mar. 23–SR	Mar. 28–May 12
Lesser Scaup Duck	Mar. 15–Apr. 25	Mar. 21–N	Mar. 15–June 9	Mar. 19–SR	Mar. 20–N
American Golden-eye	Mar. 19–Apr. 13	Apr. 3–Apr. 13	Mar. 27–May 7	Mar. 18–Apr. 5	Mar. 20–Apr. 7
Buffle-head	Apr. 9–Apr. 13	Mar. 23–May 9	Mar. 27–Apr. 20	Mar. 23–Apr. 28	Mar. 25–May 7
Ruddy Duck	Apr. 14–N	Apr. 2–N	Mar. 30–N	Apr. 12–N	Apr. 4–N
Hooded Merganser	Apr. 10	Apr. 3	Apr. 5–Apr. 16	.....	Mar. 22–Mar. 24
American Merganser	Mar. 18–Apr. 20	.....	Mar. 27–May 22	Mar. 20–Mar. 24	Mar. 20–Apr. 13
Red-breasted Merganser	Mar. 18	Apr. 11–Apr. 20	May 2–May 17	Mar. 24–Mar. 29	Apr. 11–Apr. 28
American Coot	Mar. 20–N	Mar. 14–N	.....	Mar. 19–N	Mar. 20–N

N–Nesting
SR–Summer Resident

snow on the ground just two days before the first ducks arrived. A corresponding condition existed only one day before the spring migrants arrived in 1949. Thus a relationship is suggested between the arrival of the migrant waterfowl and warm weather that results in the opening of water areas, such as the inlets and outlets of the lakes and sloughs where the melting snow and ice produce a current. The small potholes and cornfield ponds, so prominent in this part of Iowa, became free of ice in two to three days after the first arrivals in 1948 and 1949. The dates when the large lakes and sloughs first cleared of ice were March 19 in 1948 and March 30 in 1949. The dates on which the ice left the large lakes and marshes in 1938, 1939, and 1940 were March 21, March 26, and April 8, respectively [Low (8)].

The first flocks arriving ranged in number from 2 to 150 individuals, with an average of about 25. The larger flocks were usually mallards, *Anas p. platyrhynchos,* pintails, *Anas acuta tzitzihoa,* and lesser scaups, *Aythya affinis.* In 1948 nine species of waterfowl were common on the water areas by the end of the first week of migration; in 1949, 17 species. Those species present in both years by the end of March are listed in Table 1.

The first migrant geese of each species arrived about one week later in 1949 than in 1948. The main goose flight, however, occurred at about the same time during the last week of March. Considerable local interest was displayed when seven Canada geese, *Branta canadensis,* remained in the vicinity of Mud Lake until the middle of May, 1949. However, none of these Canada geese remained to nest, and the last goose was observed on May 21. The total number of observed geese migrating through the Ruthven Area in 1949 was more than three times as many as in 1948. Increases were shown by all species except the white-fronted goose, *Anser albifrons.* Even so, the total number of geese migrating through Clay and Palo Alto counties in 1949 was less than the figures given by Bennett (2) for 1934, by Low (7) for 1938, and by Provost (10) for 1942 (Table 2).

The main flight of the mallard, green-winged teal, *Anas carolinensis,* blue-winged teal, *Anas discors,* American golden-eye, *Glaucionetta clangula americana,* buffle-head, *Glaucionetta albeola,* and American merganser, *Mergus merganser americanus,* was one week earlier in 1948 than in 1949. Gadwalls, *Chaulelasmus streperus,* pintails, redheads, *Aythya americana,* and ring-necked ducks, *Aythya collaris,* reached the peak of their flights in the Ruthven Area two weeks earlier in 1948 than in 1949. Baldpates, *Mareca americana,* shovellers, *spatula clypeata,* canvas-backs, *Aythya valisineria,* and lesser scaups reached their peaks of maximum abundance at about the same time in 1948 as in 1949 (Table 3).

Those ducks that did not remain in Clay and Palo Alto counties to nest were last seen at a later date in 1949 than in 1948. In 1949 the white-fronted goose, green-winged teal, and the buffle-head remained in the area one week longer than in 1948; the blue goose, *Chen caerulescens,* and lesser snow goose, *Chen hyperborea,* two weeks; the ring-necked

duck and American merganser, three weeks; and the Canada goose, seven weeks.

The majority of the migrant species showed definite increases in observed numbers in the 1949 season over the 1948 season. Those species that were noticeably increased were the mallard, 250 per cent; gadwall, 300 per cent; canvas-back, 60 per cent; lesser scaup, 30 per cent; and ruddy duck, *Erismatura jamaicensis rubida,* 900 per cent. The numbers of migrating green-winged teal, shovellers, redheads, American golden-eyes, and buffle-heads remained relatively unchanged for the two years. Five species indicated a decrease in numbers; namely, the American coot, *Fulica americana,* 16 per cent; ring-necked duck, 20 per cent; pintail, 30

TABLE 2

COMPARATIVE NUMBERS OF WATERFOWL OBSERVED IN CLAY AND PALO ALTO COUNTIES, IOWA

Species	Number Seen				
	1934	1938	1942	1948	1949
	(*Bennett*)	(*Low*)	(*Provost*)	(*Glover*)	(*Glover*)
Canada Goose	5,000	7,000	10,000	596	6,961
White-fronted Goose	200	300	4,000	390	91
Lesser Snow Goose	20,000	15,000	4,000	1,007	3,925
Blue Goose	30,000	50,000	20,000	5,404	12,153
Mallard	400,000	250,000	280,000	25,323	67,171
Gadwall	10,000	8,000	2,500	1,769	3,003
Baldpate	8,000	10,000	12,000	1,712	2,058
Pintail	1,000,000	500,000	460,000	26,879	18,795
Green-winged Teal	8,000	10,000	11,000	1,252	1,064
Blue-winged Teal	20,000	30,000	35,000	14,467	4,408
Shoveller	15,000	25,000	15,000	2,822	2,856
Wood Duck	.....	.....	50	.....	11
Redhead	1,000	3,500	4,500	1,108	1,275
Ring-necked Duck	8,000	10,000	8,500	5,621	4,843
Canvas-back	300	500	12,000	830	1,986
Lesser Scaup Duck	20,000	40,000	230,000	27,997	40,286
American Golden-eye	300	30	300	186	172
Buffle-head	50	200	250	78	85
Ruddy Duck	500	1,000	300	167	1,241
Hooded Merganser	40	35	50	.....	11
American Merganser	100	.....	200	133	1,004
Red-breasted Merganser	60	70	100	8	105
American Coot	30,000	50,000	.....	57,900	48,398

per cent; blue-winged teal, 64 per cent; and white-fronted goose, 77 per cent. The observed populations in either 1948 or 1949 were not comparable to those of 1934, 1938, or 1942, especially in the total numbers of mallards and pintails (Table 2).

SEX RATIO

The sex ratio trend and the per cent of paired migrants during the spring migration are presented in Fig. 1. An excess of male ducks was evident in the 14 species analyzed for sex ratio.

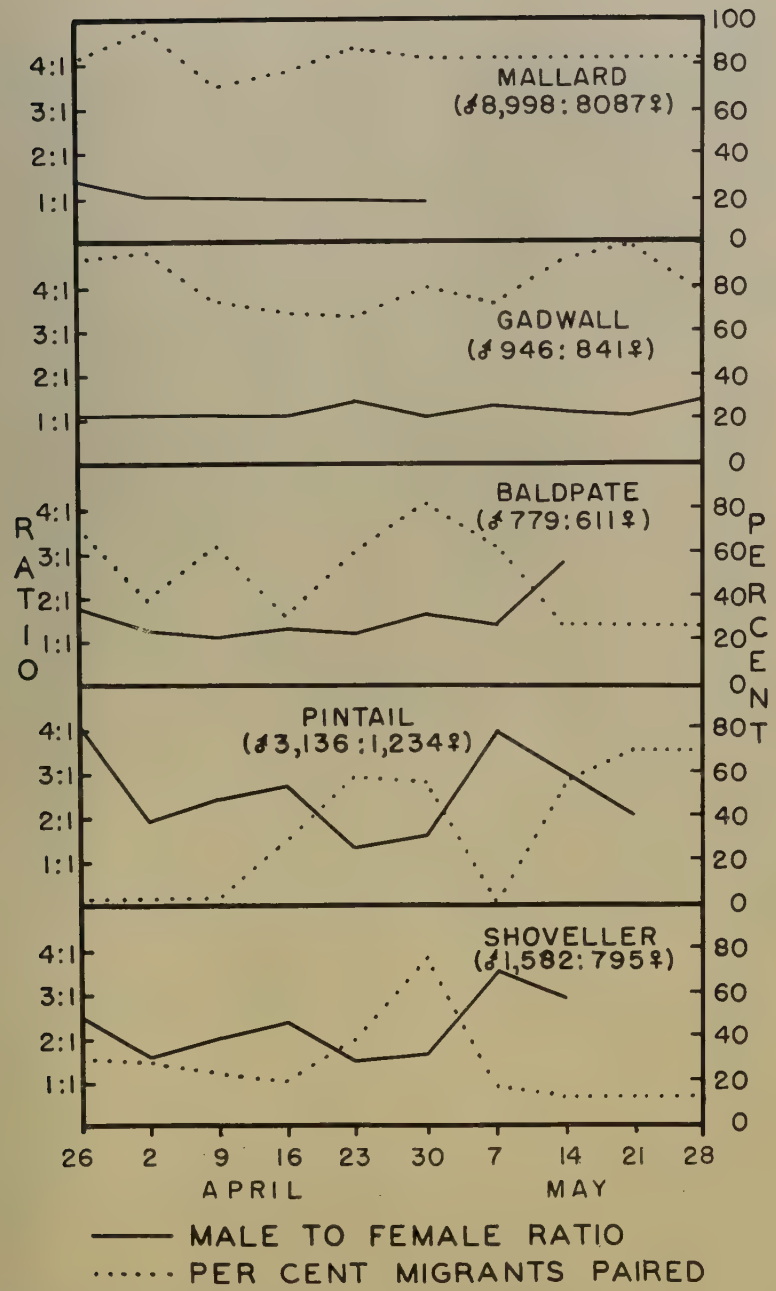


Fig. 1.—The sex ratio trend and the per cent of paired waterfowl in Clay and Palo Alto counties, Iowa, Spring, 1949.

In 1948 there was a preponderance of males in the first flights of mallards to arrive. This was not true in 1949, for more than 80 per cent of the mallards were paired upon arrival. The mallard sex ratio at the forepart of the 1949 migration was about 1.4 males to 1.0 females. After two weeks of migration the sex ratio tended to be stabilized at a one to one ratio.

At no time during the 1949 spring migration did the sex ratio of the baldpate approach a one to one ratio. Migrating females were often observed with two or three attendant males. Furthermore, less than 60 per cent of the baldpates observed during the migration were paired.

During the first days of the 1948 spring migration of pintails as many

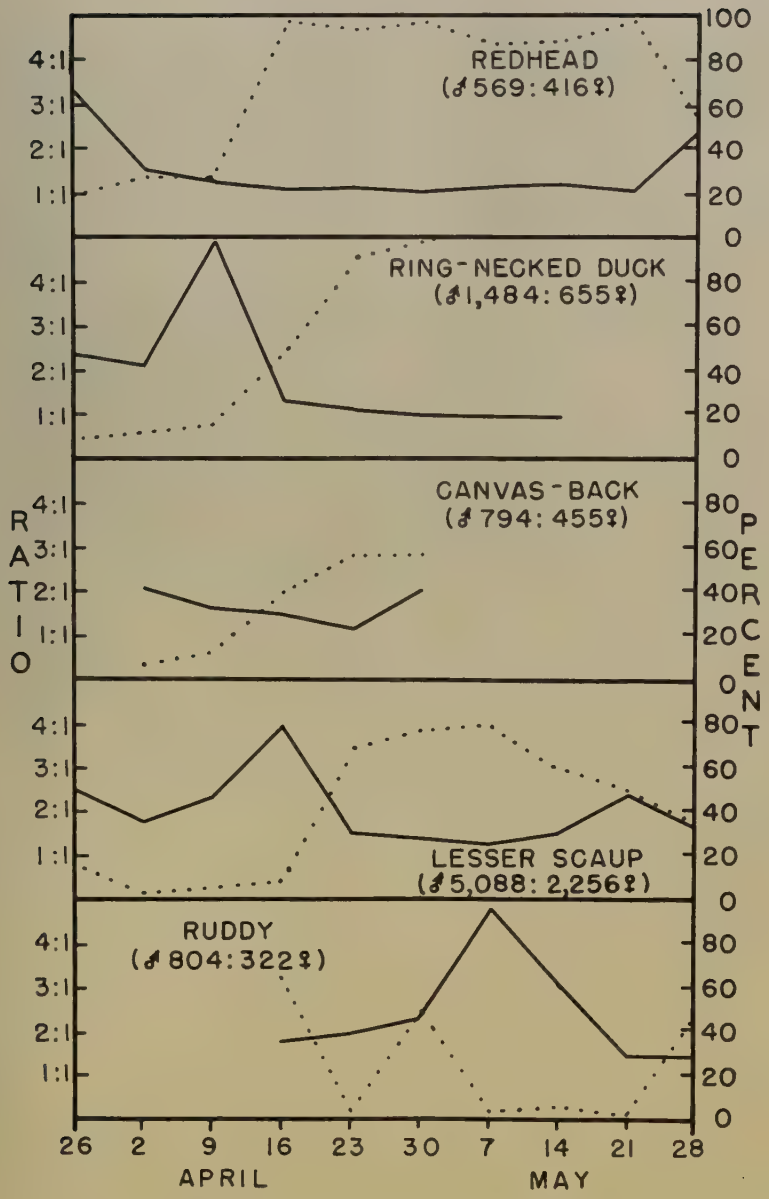
TABLE 3

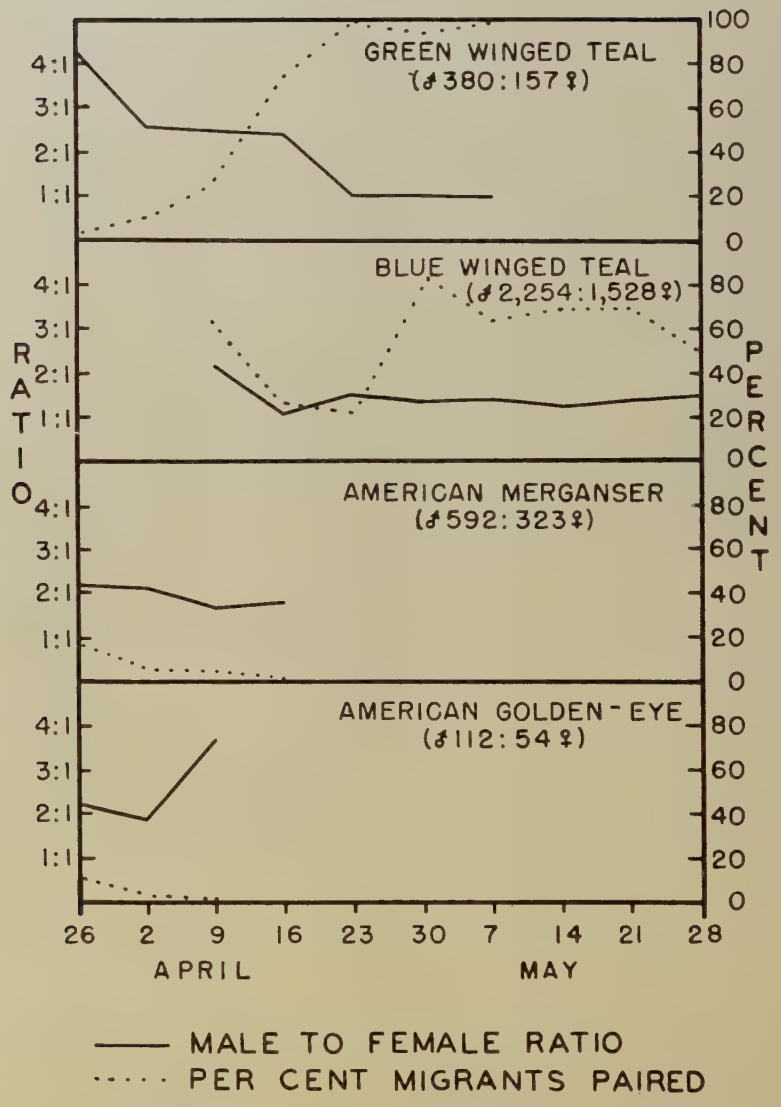
A Comparison of the Main Spring Flights of Waterfowl in Clay and Palo Alto Counties, Iowa

Species	1934	1938	1942	1948	1949
	(*Bennett*)	(*Low*)	(*Provost*)	(*Glover*)	(*Glover*)
Canada Goose	Apr. 17	Apr. 10	Apr. 15	Mar. 23	Mar. 25
White-fronted Goose	Apr. 12	Mar. 29	Mar. 27	Mar. 26	Mar. 30
Lesser Snow Goose	Apr. 16	Apr. 10	Mar. 27	Mar. 22	Apr. 1
Blue Goose	Apr. 15	Mar. 31	Mar. 29	Mar. 25	Apr. 1
Mallard	Apr. 14	Apr. 4	Mar. 30	Apr. 7	Apr. 1
Gadwall	Apr. 19	Mar. 24	Apr. 2	Apr. 9	Apr. 2
Baldpate	Apr. 19	Apr. 8	Apr. 12	Apr. 6	Apr. 9
Pintail	Apr. 14	Apr. 5	Mar. 24	Apr. 10	Mar. 30
Green-winged Teal	Apr. 14	Apr. 18	Apr. 12	Apr. 6	Apr. 3
Blue-winged Teal	Apr. 25	Apr. 19	Apr. 27	Apr. 20	Apr. 24
Shoveller	Apr. 13	Apr. 15	Apr. 5	Apr. 14	Apr. 20
Wood Duck	.....	.....	May 24	.....	Apr. 16
Redhead	Apr. 8	Apr. 6	Apr. 6	Apr. 4	Apr. 14
Ring-necked Duck	Apr. 12	Mar. 29	Apr. 1	Mar. 27	Apr. 6
Canvas-back	Apr. 9	Apr. 18	Apr. 2	Apr. 1	Apr. 4
Lesser Scaup Duck	Apr. 15	Apr. 9	Mar. 30	Apr. 6	Apr. 8
American Golden-eye	Mar. 31	Apr. 3	Mar. 30	Mar. 22	Mar. 27
Buffle-head	Apr. 13	Apr. 1	Apr. 8	Mar. 27	Apr. 2
Ruddy Duck	Apr. 18	Apr. 29	Apr. 4	May 17	Apr. 30
Hooded Merganser	.....	May 10	Apr. 10	.....	Mar. 23
American Merganser	Apr. 10	.....	Apr. 15	Mar. 22	Apr. 1
Red-breasted Merganser	.....	Apr. 11	May 5	Mar. 25	Apr. 24
American Coot	Apr. 24	Apr. 24	.....	Apr. 10	Apr. 16

as 600 males were counted before a female was observed. This unbalanced sex ratio was reduced from week to week, but even by the end of the spring flight it was not below two males to one female. In 1949 the sex ratio changed erratically from week to week but was not as unbalanced as during the first two weeks of migration in 1948. The final sex ratio of two males to one female was commensurate with that observed in 1948.

The first green-winged teal to arrive in 1948 were predominantly


REDHEAD
(♂569:416♀)
RING-NECKED DUCK
(♂1,484:655♀)
CANVAS-BACK
(♂794:455♀)
LESSER SCAUP
(♂5,088:2,256♀)
RUDDY
(♂804:322♀)
RATIO
PER CENT
4:1
3:1
2:1
1:1
100
80
60
40
20
0
26 2 9 16 23 30 7 14 21 28
APRIL
MAY
MALE TO FEMALE RATIO
PER CENT MIGRANTS PAIRED


GREEN WINGED TEAL
(♂380:157♀)
BLUE WINGED TEAL
(♂2,254:1,528♀)
AMERICAN MERGANSER
(♂592:323♀)
AMERICAN GOLDEN-EYE
(♂112:54♀)
RATIO
PERCENT
4:1
3:1
2:1
1:1
100
80
60
40
20
0
26 2 9 16 23 30 7 14 21 28
APRIL
MAY
MALE TO FEMALE RATIO
PER CENT MIGRANTS PAIRED

males. The sex ratio gradually changed from four males to one female at the onset of migration to one to one during the last three weeks.

In 1948 the early flocks of blue-winged teal had a sex ratio of about 3.0 males to 1.0 females, and in 1949, 2.2 males to 1.0 females. By the end of the migration in 1948 the records indicated a balanced sex ratio like that reported by Bennett (1), but in 1949 there was a ratio of 1.5 males to 1.0 females at the beginning of the nesting season. This sex ratio coincided closely with those reported by Lincoln (6), Erickson (3), and Furniss (4 and 5).

The first flocks of redheads to arrive in Clay and Palo Alto counties in both 1948 and 1949 had a sex ratio of about three males to one female. The mean sex ratio during the 10-week migration period was 1.6 males to 1.0 females. Low (9) gave the mean sex ratio of 3,400 redheads sexed during the spring migrations of 1938, 1939, and 1940 as 1.4 males to 1.0 females.

With the exception of a noticeable preponderance of males in the migrant ring-necked ducks during the first week of April in 1949, the sex ratio tended to reach a one to one ratio by the middle of May.

The greatest number of paired lesser scaups in migration were observed from April 23 to May 14, 1949. Less than 38 per cent of the late migrants appeared to be paired, although the sex ratio was 1.7 males to 1.0 females.

American golden-eyes were not abundant but were among the earliest of ducks to arrive in the area. Observations in 1949 showed that about 10 per cent of the first migrants were paired, but as the migration continued, this percentage declined to less than 2 per cent.

SUMMARY

1. The total number of waterfowl on the lakes and marshes of Clay and Palo Alto counties in 1949 was about 26 per cent more than in 1948 but only about 20 per cent of the total for 1934, 1938, or 1942. The decrease in the total numbers of mallards and pintails from 1934 to 1949 is the most noticeable.

2. A close relationship was suggested between the spring arrival of waterfowl and warm temperatures that result in the opening of water areas, such as outlets and inlets of lakes and sloughs.

3. Ten species of ducks reached their peaks of maximum abundance from one to two weeks earlier in 1948 than in 1949.

4. The sex ratio trend and the per cent of paired waterfowl during the spring migration are presented for 14 species of ducks.

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ON THE EXISTENCE AND RELATIVE STABILITY OF HAFNIUM PEROXIDE

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Contribution No. 134 from the Institute for Atomic Research and Department of Chemistry, Iowa State College, Ames, Iowa. Work was performed in the Ames Laboratory of the Atomic Energy Commission.

Received November 25, 1950

Alkali soluble peroxyzirconate ion has been prepared and rather extensively studied. Hafnium is reported (1) to yield a peroxy compound under the same conditions in alkali, but the compound is reported to have a different solubility from the zirconium compound. The acid peroxysulfate of hafnium is reported not to exist, while zirconium forms such a compound (1).

The following set of experiments and the data obtained from them indicate not only that hafnium peroxide exists, but that it has almost exactly the same solubility and stability toward decomposition into the hydrous oxide and oxygen as does zirconium peroxide.

1. To 100 ml. of water were added 25 g. $ZrCl_4$, containing 1.33 per cent Hf, followed by 50 ml. of 30 per cent H_2O_2 and NH_4OH until an odor of ammonia was distinctly present in the solution. At this point a hydrous zirconium peroxide is quantitatively precipitated. After filtering, the precipitate is partially dissolved in 300 ml. of 0.2 M KOH containing 25 ml. of 30 per cent H_2O_2. Upon heating the solution, oxygen is evolved, and in from one to three minutes of heating at 90–100°C. precipitate is formed which is the first portion of the hydrous zirconium oxide from the decomposed peroxyzirconate; this precipitate, containing about 10 per cent of the original metal, was analyzed spectrographically. The hafnium content was 1.22 per cent.

2. The filtrate from the above preciptate was rapidly cooled and allowed to stand at room temperature over night. The remainder of the material had precipitated, and the precipitate was found to contain 1.29 per cent hafnium.

3. The hydrous oxide from step 2 was redissolved in 250 ml. of 2M KOH containing 50 ml. of 30 per cent H_2O_2. This was insufficient peroxide to dissolve all of the precipitate, and a small portion, about 5 per cent of the material, was filtered off and analyzed, the result being 1.47 per cent Hf.

4. After standing one hour, the remainder of the material in solution had precipitated; this material contained 1.28 per cent Hf.

5. A solution identical to that in number one of the peroxyzirconate was treated with portions of formaldehyde to gradually reduce the hydrogen peroxide in equilibrium with the peroxy ions. This technique al-

lowed somewhat closer control of the rate of removal of H_2O_2. The material was precipitated in three approximately equal consecutive portions containing respectively 1.14, 1.09, and 1.39 per cent hafnium.

6. A 25 mg. sample 97 per cent hafnium in the form of the tetrachloride was treated with 0.5 ml. of H_2O_2 and an excess of 2M KOH. A clear solution was formed, showing that zirconium need not be present to solublize the hafnium.

7. A solution of 25 g. Zr as oxide in 6M H_2SO_4 was treated with 10 ml. of 30 per cent H_2O_2 and cooled in an ice bath. A peroxyzirconium sulfate was formed. The precipitate contained 1.33 per cent Hf.

Since all of the above analyses have an accuracy of about $\pm$ .2 per cent it is seen that Hf peroxy compounds are extremely similar to those of Zr, both in solubility and reactivity. The spectrographic analyses were done by Dr. Velmer Fassel.

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GROWTH STUDIES OF THE YELLOW PERCH, *PERCA FLAVESCENS* (MITCHILL), IN THREE NORTHWEST IOWA LAKES[1]

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Received November 25, 1950

Spirit Lake, West Okoboji and East Okoboji are located in Dickinson County in northwest Iowa. These three eutrophic lakes are respectively the first, second, and fifth largest lakes in Iowa and are popular resort areas in the summer. The annual fishing demand is high and the yellow perch provide much in the way of sport and food as well as acting as a "buffer" for the more desirable but less common species of fish in the lakes.

The morphometry of West Okoboji [Birge and Juday, (2)] is much different from that of East Okoboji or Spirit Lake. West Okoboji has a trough-shaped bottom profile. It has an area of 3,788 acres with a maximum depth of 132 feet and a mean depth of 40.4 feet. The shore line is irregular and is 18.2 miles long. A strongly marked thermocline is present in the summer between the depth of 33 and 45 feet. The long axis of the lake is 5.46 miles and the greatest width is 2.48 miles. Compared to the turbid waters of Spirit Lake and East Okoboji, West Okoboji is relatively clear.

Spirit Lake has an area of 5,684 acres and has a maximum depth of 27 feet with over 26 per cent of the area exceeding 20 feet in depth. The bottom profile is saucer-shaped, and only 5 per cent of the area is from 0 to 8 feet in depth. The north-south axis is 4 miles long and the east-west axis is 3.5 miles long. Most of Spirit Lake's watershed is in Minnesota. No streams of significance flow into Spirit Lake or either of the Okobojis.

East Okoboji has approximately 1,800 surface acres and is connected to West Okoboji on the south. East Okoboji has a maximum depth of approximately 26 feet, but most of the lake is less than 10 feet deep. The long axis is approximately six miles with the widest span of about one mile. The water levels of East and West Okoboji are approximately the same, but the water level of Spirit Lake is at least six feet higher than that of East Okoboji. During periods of high water, water flows from Spirit Lake into East Okoboji through a concrete spillway. The drainage from Spirit Lake and West Okoboji is through East Okoboji and from

[1] Journal Paper No. J-1826 of the Iowa Agricultural Experiment Station, Ames, Iowa, Project No. 764, and the Industrial Science Research Institute, Project No. 45, of Iowa State College; in cooperation with the Iowa State Conservation Commission.

[2] Now with the Tennessee Game and Fish Commission, Crossville, Tennessee.

there into Upper Gar Lake, Minnewashta Lake, Lower Gar Lake and finally into the east fork of the Little Sioux River.

MATERIALS AND METHODS

These growth studies of the yellow perch of Spirit Lake, West Okoboji, and East Okoboji are based on scale samples taken since 1941. The 1941 data were collected by Thomas Moen and Max Davis, the 1942, 1943, and 1945 data by William Sigler, and 1949 data were collected by the author. Methods of capture included angling, experimental gill nets, and 400 to 500 foot seines with a ¼-inch mesh.

Standard length measurements were used in this study although in

TABLE 1

AVERAGE GROWTH RATES OF YELLOW PERCH IN EACH AGE GROUP FOR THE 1941, 1942, 1943, 1945, AND 1949 COLLECTIONS FROM SPIRIT LAKE

Year	Age Class	Number Examined	Standard Length in Mm. at Each Annulus						Standard Length at Capture
			1	2	3	4	5	6	
1941.	II	3	45	124					190
	III	46	54	157	215				246
	IV	11	51	144	206	236			251
Average Annual Increment			53	100	57	30			
1942.	I	9	63						132
	II	1	42	138					182
	III	3	49	142	185				209
	IV	2	44	141	192	214			239
Average Annual Increment			55	93	46	22			
1943.	II	16	61	160					160
	III	2	61	155	223				223
	IV	56	55	153	215	247			247
	V	71	58	154	211	237	254		254
	VI	1	62	160	215	234	244	252	252
Average Annual Increment			57	97	57	28	15	8	
1945.	III	5	48	124	196				231
	IV	3	49	127	186	212			232
	V	7	47	129	194	234	252		266
	VI	1	62	157	206	231	254	266	277
Average Annual Increment			49	80	65	34	18	12	
1949.	I	3	46						127
	II	11	46	124					173
	III	7	48	105	159				188
	IV	18	54	117	167	198			213
Average Annual Increment			50	67	51	31			
Average Standard Length for 266 Fish			55	147	204	235	254	259	

most cases total and fork lengths were also recorded. The following conversion factors were calculated:

Total length — 1.19 standard lengths
Total length — 1.04 fork lengths
Fork length — 1.15 standard lengths

The ages of the yellow perch were determined by counting the number of annuli on the scales. The scales were prepared for projection as described by Lewis and Carlander (8). A microprojector similar to that described by Van Oosten, Deason, and Jobes (11) was used, with a magnification of 42 diameters. The number of annuli is expressed by Roman numerals, representing the age class of the fish.

No body-scale relationship was calculated for the perch in this study due to inconsistencies in the place of selection of the scales during the years involved. The growth was calculated on the assumption of direct proportion between the scale measurements and the length of the fish at the time of annulus formation.

GROWTH RATE

The West Okoboji perch appear to have a slower growth rate than those from East Okoboji and Spirit Lake (Tables 1 and 2). Comparison

TABLE 2

AVERAGE GROWTH RATES OF YELLOW PERCH IN EACH AGE GROUP FOR THE 1941 AND 1949 COLLECTIONS FROM WEST OKOBOJI AND THE 1949 COLLECTION FROM EAST OKOBOJI

Year	Age Class	Number Examined	Standard Length in Mm. at Each Annulus				Length at Capture
			1	2	3	4	
West Okoboji							
1941	I	2	48	.....	.....	.....	130
	II	9	48	115	.....	.....	165
	III	2	41	104	165	166	194
	IV	1	44	99	134	166	198
Average Annual Increment			47	65	52	32	.....
1949	I	26	56	.....	.....	.....	107
	II	23	41	103	.....	.....	144
	III	14	38	91	151	.....	176
	IV	8	52	121	167	196	210
Average Annual Increment			47	60	55	29	.....
Average Standard Length for 85 Fish			47	104	157	193	.....
East Okoboji							
1949	I	70	62	.....	.....	.....	145
	II	28	55	148	.....	.....	191
	III	94	56	152	192	.....	210
	IV	8	66	146	189	210	225
Average Annual Increment			58	95	40	21	.....
Average Standard Length for 211 Fish			58	151	192	210	.....

of the growth rates of the perch from these lakes with those from other areas [Schneberger (10); Lewis (7); Carlander (1); Jobes (6); Hile (3); Hile and Jobes (4) and (5); and Parsons (9)] suggests that the Spirit Lake and East Okoboji perch are fast-growing and the perch from West Okoboji are about average in growth rate.

From 1941 to 1949, the Spirit Lake perch show only minor fluctuations in growth rate. The perch collected in 1949 show the lowest total growth, but the low average annual increment for the second year appears to be mostly responsible for this. In all three lakes, the yellow perch appear to have the most growth during the second year.

LENGTH-WEIGHT RELATIONSHIP

Besides being slower growing, the West Okoboji perch apparently are also lighter for their length than those from East Okoboji and Spirit Lake (Table 3). Based on these data, the relationships between standard

TABLE 3

AVERAGE WEIGHTS IN GRAMS AT VARIOUS STANDARD LENGTHS OF THE YELLOW PERCH OF SPIRIT LAKE, WEST AND EAST OKOBOJI

Standard Lengths in Mm.	Spirit Lake		East Okoboji		West Okoboji		Combined	
	Number	Average Weight	Number	Average Weight	Number	Average Weight	Number	Weight Range
70–79	1	7					1	
80–89	1	11			1	10	2	10–11
90–99					5	14	5	13–17
100–109			2	25	7	15	9	12–28
110–119	1	28			12	25	13	19–32
120–129	1	42	2	40	1	32	4	32–42
130–139	1	46	20	54	12	45	33	37–79
140–149	4	61	22	60	5	57	31	42–67
150–159	8	79	16	80	11	74	35	61–92
160–169	9	94	8	93	6	82	23	42–99
170–179	5	115	8	116	10	100	23	62–124
180–189	7	137	5	134	2	129	14	122–171
190–199	8	164	25	169	5	143	38	137–192
200–209	12	206	45	190	4	181	61	165–241
210–219	22	235	27	221	2	237	51	160–269
220–229	23	264	15	250			38	226–284
230–239	18	318	17	284			35	269–354
240–249	26	361					26	298–454
250–259	51	414					51	326–496
260–269	25	449					25	333–510
270–279	9	511					9	482–539

length in millimeters (L) and weight in grams (W) of the Spirit Lake, East and West Okoboji perch are described by the following formulas:

Spirit Lake

$$\text{Log } W = -5.48713 + 3.36778 \text{ Log } L$$

East Okoboji

$$\text{Log } W = -5.0120 + 3.1560 \text{ Log } L$$

West Okoboji

$$\text{Log } W = -5.51726 + 3.35460 \text{ Log } L$$

The East Okoboji perch apparently do not become heavier as they increase in length to the degree that the perch from the other lakes do.

The relative plumpness of a fish may be represented by the coefficient of condition, K, where

$$K = \frac{W\,10^5}{L^3}$$

W = weight in grams
L = standard length in millimeters

In most cases the yellow perch of Spirit Lake and the Okoboji show an increase in K, with an increase in age (Table 4). The calculated length-weight relationships indicate that the weight increases more rapidly than the cube of the length which would result in an increase in K with an increase in length. There is an indication that the condition of Spirit Lake

TABLE 4

AVERAGE COEFFICIENTS OF CONDITION, K, FOR EACH AGE CLASS OF THE YELLOW PERCH OF SPIRIT LAKE, WEST OKOBOJI, AND EAST OKOBOJI

Age Class	Spirit Lake				West Okoboji		East Okoboji
	1941	1943	1945	1949	1941	1949	1949
I				1.89(3)	1.80(2)	1.56(26)	2.13(70)
II	2.32(3)	2.14(16)		2.11(11)	1.75(9)	1.89(23)	2.21(28)
III	2.48(46)	2.45(2)	2.37(5)	2.23(7)	1.53(2)	1.99(14)	2.25(94)
IV	2.60(11)	2.45(56)	2.37(3)	2.23(18)	2.46(1)	2.02(8)	2.29(8)
V		2.56(71)	2.48(7)				
VI		2.57(1)	2.60(1)				

Number of specimens in parentheses.

yellow decreased during the period of study. The lower average K values for the West Okoboji yellow perch are a reflection of the lower length-weight relationship already referred to.

ACKNOWLEDGMENTS

Appreciation is expressed by the author to Dr. Kenneth D. Carlander, Department of Zoology and Entomology, Iowa State College, for assistance in the preparation of this paper; to Earl T. Rose and Thomas Moen of the Iowa Conservation Commission for assistance in the field; to Max Davis and William Sigler for the use of their collection; and to Carlyle Parsons whose aid in the field was invaluable.

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THE GENUS *SETARIA* IN IOWA[1]

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Received December 5, 1950

The grass genus *Setaria* is represented in Iowa by four introduced weedy species, one introduced cultivated species, and one rare native species. In 1949, *S. faberii,* a recent introduction to the United States, was discovered in Iowa. Here it is already proving to be a vigorous weed, and its probable future importance makes it desirable to review the distribution and distinguishing characteristics of all of our representatives of the genus. The distribution records here presented are based upon specimens deposited in the herbaria of the Iowa State College and the State University of Iowa. The author wishes to thank Dr. Robert Thorne, Curator of the Herbarium at the latter institution, for lending some of the specimens studied. The illustrations of the species were made by Elsie Herbold Froeschner.

KEY TO SPECIES OF *SETARIA* FOUND IN IOWA

1. Bristles of the panicle upwardly barbed; lower internodes of the dense panicle concealed by the spikelets and bristles.
   2. Sheaths with membranous entire margins, not ciliate; fertile lemma strongly wrinkled, its upper half exposed.
      3. Culms in large tufts from fibrous root systems; plants annual; spikelets ovate, (2.8–) 3.0–3.4 mm. long.....1. *S. lutescens*
      3. Culms arising singly or in small tufts from knotted, brittle, much-branched rhizomes; plants perennial; spikelets elliptic, 1.9–2.8 (–3.0) mm. long..... .....2. *S. geniculata*
   2. Sheaths short-ciliate on the margins; fertile lemma wrinkled or nearly smooth, usually covered by the second glume except at the tip.
      4. Spikelets falling entire, the fruit remaining covered by the glumes and sterile lemma.
         5. Leaf blades glabrous above; spikelets 1.9–2.2 mm. long.....4. *S. viridis*
         5. Leaf blades villous above; spikelets 2.6–2.9 mm. long.....6. *S. faberii*
      4. Spikelets when mature disarticulating above the glumes and sterile lemma, the fruit shelling out, leaving glumes and lemma on the panicle; cultivated plants .....5. *S. italica*
1. Bristles of the panicle downwardly-barbed, adhering to objects when brushed upward; lower internotes of panicles usually exposed between the somewhat distant verticils .....3. *S. verticillata*

1. *Setaria lutescens* (Weigel) F. T. Hubb. YELLOW FOXTAIL. Figs. 1, 7.
   Setaria glauca Beauv., not *Panicum glaucum* L.[2]

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[1] Journal Paper No. J-1868 of the Iowa Agricultural Experiment Station. Project 1136.

[2] H. Trimen, in Jour. Linn. Soc. London (Botany), 1887, p. 136, shows that this name is based upon a specimen of pearl millet (*Pennisetum glaucum* (L.) R. Br.) and is not applicable to yellow foxtail.

This is one of our commonest weeds, found in abundance throughout the state. It is especially abundant in cornfields, but occurs wherever the soil is frequently disturbed. July—October.

Yellow foxtail is widely distributed from South Dakota to eastern Texas and eastward, and to a lesser extent in the western states. Introduced from Europe.

2. *Setaria geniculata* (Lam.) Beauv. Figs. 2, 8

This is our only perennial species. The culms are easily detached from the rather brittle rhizomes, so the plants might be confused with the similar yellow foxtail. On the average, this species has shorter panicles and narrower leaves than yellow foxtail. The fruits tend to be purple near the tip, whereas those of yellow foxtail are stramineous. Our only collection from Iowa is listed below. Literature reports of this species from Iowa are based upon specimens of *S. lutescens*.

IOWA: Jones County. Few, in a damp hollow along railroad tracks; sandy plain, bottoms of Wapsipinicon River; n.w. ¼ sec. 18, Oxford Twp. August 21, 1948. Richard W. Pohl 6607. Herb. Iowa State College.

In the United States, this species is found primarily on the Atlantic and Gulf Coastal Plains, but extends northward on the Mississippi Embayment to Illinois and southeastern Iowa, and occurs sparingly in the southwestern states. Native to the Americas, it extends from coastal Massachusetts to California, Argentina and Chile. July—September.

3. *Setaria verticillata* (L.) Beauv. BRISTLY FOXTAIL. Figs. 3, 9

The retrorsely-barbed bristles of this species cling to any roughened objects which they touch. It is common to see the panicles tangled into masses by the cohering bristles. They also adhere to hair of animals and clothing. Bristly foxtail is locally common in cornfields and similar disturbed habitats in Iowa. An introduction from Europe, it is now distributed from Massachusetts to North Dakota and California, southward to Louisiana and Alabama. June—October. A rare form, var. *ambigua* (Guss.) Parl. has upwardly-barbed bristles, but is otherwise similar to typical *S. verticillata*. It has not yet been found in Iowa.

4. *Setaria viridis* (L.) Beauv. GREEN FOXTAIL. Figs. 4, 10

This is a very common weed of cornfields and disturbed ground throughout Iowa. The panicles are much softer than those of the preceding two species and have slightly nodding tips. Occasional plants may have purple bristles in the panicle.

Green foxtail, introduced from Europe, is now distributed throughout the United States and southern Canada. July—September.

Occasionally found in stands of green foxtail are tall, vigorous, broad-leaved forms with large panicles, resembling millet except that the spikelets disarticulate below the glumes, and the panicles show little lobulation. While they have been named (as *S. viridis*, var. *major* Gaud.), the proper

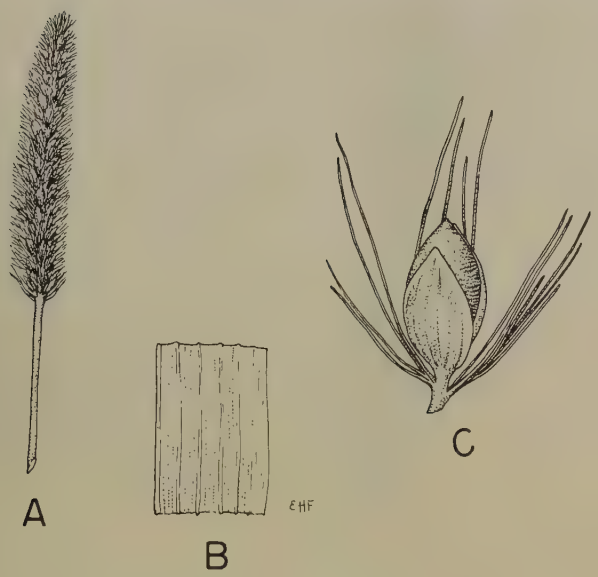

FIG. 1.—*Setaria lutescens.* A. panicle x .7 B. sheath margin x 6 C. spikelet with subtending bristles x 6.

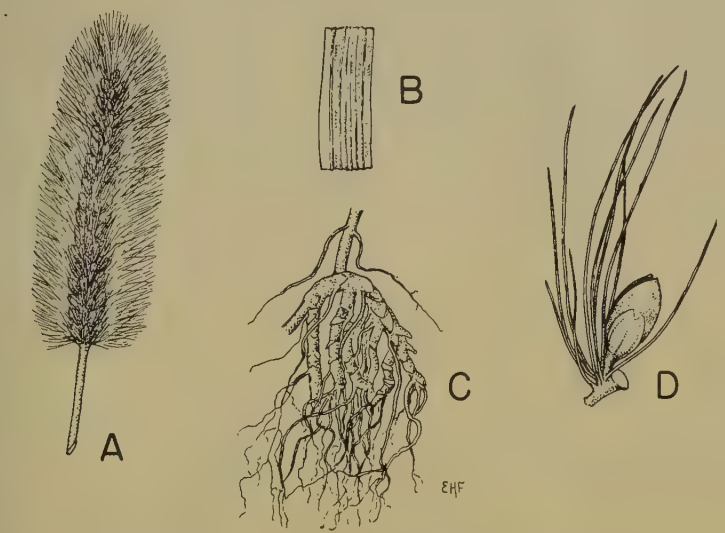

FIG. 2.—*Setaria geniculata.* A. panicle x 1.4 B. sheath margin x 6 C. base of culm with rhizomes x 6 D. spikelet with subtending bristles x 6.

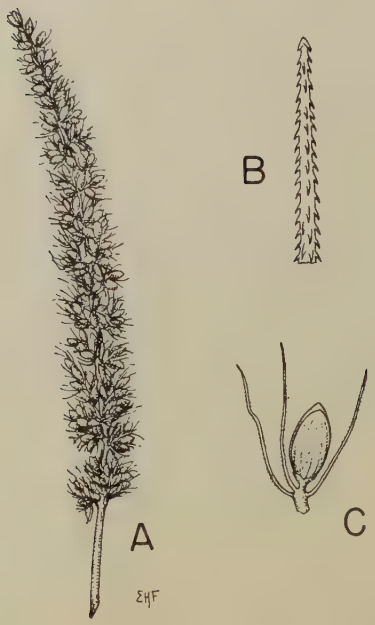

FIG. 3.—*Setaria verticillata*. A. panicle x .7 B. bristle, showing barbing, x 28 C. spikelet with subtending bristles x 6.

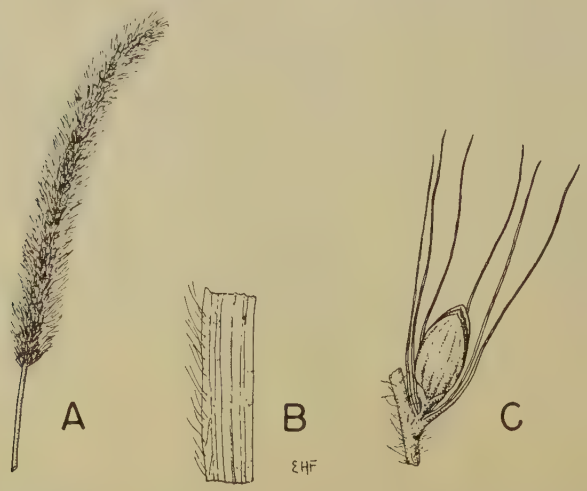

FIG. 4—*Setaria viridis*. A. panicle x .7 B. sheath margin x 6 C. spikelet with subtending bristles x 6.

taxonomic position of these plants has been puzzling. Recent studies on the genetics of millet by Li and his co-workers (3) show almost complete sterility exists between *S. viridis* and *S. italica*. While the morphologic differences between the two are not large, and mostly of a quantitative nature, the presence of this sterility barrier indicates they are properly considered as independent species. The best qualitative distinction between *S. viridis* and *S. italica* is the site of disarticulation, below the glumes in the former and above the sterile lemma in the latter. Li *et al.* showed this characteristic is controlled by two pairs of complementary factors, with disarticulation below the glumes dominant. This suggests a possible manner of origin for the millet-like plants mentioned above. Because of the sterility barrier, natural crossing must occur only rarely. However, once the genes for the *viridis*-type disarticulation were introduced into *S. italica*, individuals with this type of disarticulation might segregate out thereafter. Some of these would be expected to have the size and vigor of millet. In some cases, such millet-like plants occur on agricultural lands, where they appear to persist after cultivation of millet.

5. *Setaria italica* (L.) Beauv. FOXTAIL MILLET, HUNGARIAN MILLET, COMMON MILLET, etc. Figs 5, 11

The foxtail millets are lush, coarse grasses resembling green foxtail. Many different agronomic varieties exist, differing color of fruits and bristles, degree of lobing of the panicle, and other characteristics. Millet is frequently found as an escape, or persisting around fields. Eurasian. July—September.

6. *Setaria faberii* Herrm. Beitrage Biol. Pflanzen 10:51. (1910) NODDING FOXTAIL Figs. 6, 12

This species, apparently a recent introduction to this country, has been spreading rapidly and will probably become one of our more important weeds in clean-tilled crops. The plants resemble green foxtail, but are larger in all of their parts. On rich, moist soil, plants have been observed up to two and a half meters tall. Panicles on strong plants may reach 17 to 18 cm. in length and 2 to 3 cm. in diameter, including the bristles. Nodding foxtail may readily be distinguished from green foxtail and millet by its villous leaf blades. The panicles of nodding foxtail droop from a point near their bases, the whole inflorescence hanging down or arching, while those of green foxtail merely nod near the apex. The color of the foliage is rather yellowish green, in contrast to the darker olivaceous green of *S. viridis*.

While unrecognized in Iowa before 1949, nodding foxtail is widespread and locally abundant in the southern half of the state. To achieve such a degree of spread, it must have been in the state for some years. The first known occurrence was on the alluvium along the Des Moines River in Dolliver State Park, Webster County, in July, 1949. Subsequent field investigations in southern Iowa showed this species occurs in thirty six counties, from Fremont, Harrison, and Crawford Counties

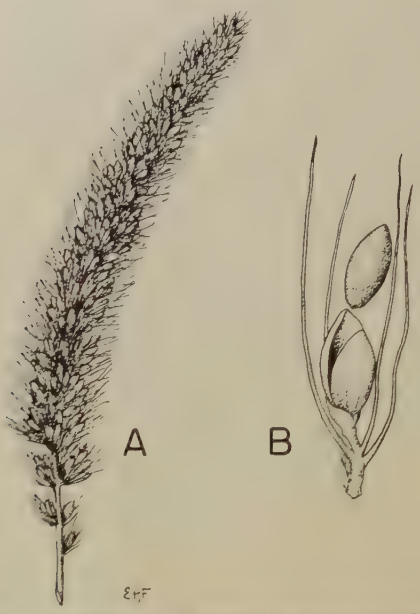

FIG. 5.—*Setaria italica*. A. panicle x .7 B. spikelet with subtending bristles, showing disarticulation of fruit x 6.

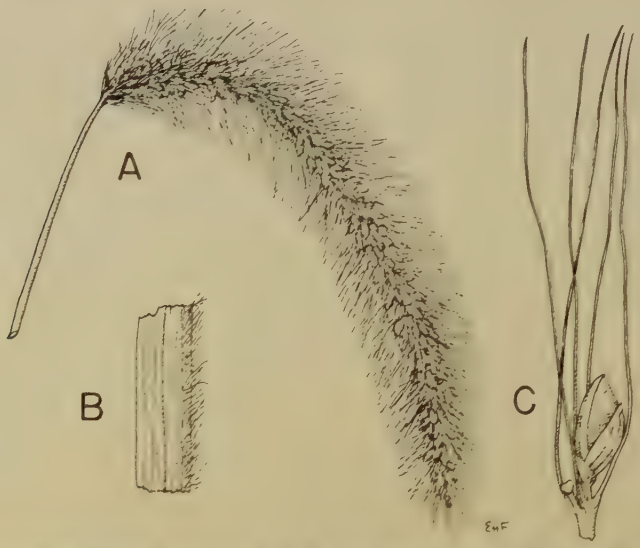

FIG. 6.—*Setaria faberii*. A. panicle x .7 B. sheath margin x 6 C. spikelet with subtending bristles x 6.

on the west to Jones and Lee Counties on the east. Since all of these occurrences were located in two seasons, it is reasonable to suspect that the plant will also be located at many other points within this general area. Despite a number of attempts to locate it in the northern counties, it has not yet been found there. The preferred habitat of nodding foxtail is rich, moist, disturbed soil—ideal corn-growing conditions are also

Ranges of species of *Setaria* in Iowa: 7. *S. lutescens* 8. *S. geniculata* 9. *S. verticillata* 10. *S. viridis* 11. *S. italica* 12. *S. faberii*

excellent for *S. faberii.* The plant has been located in a number of places growing in stands of red clover. Frequently one clover field will be heavily infested, while adjacent ones will be completely free of this weed. Seed analysts in the Iowa State College Seed Laboratory have

recently been finding seed of *S. faberii* in lots of red clover seed, which may be serving as a medium for the dispersal of nodding foxtail. At several sites, farm gardens were heavily infested with *S. faberii*, while the adjacent fields were free of it. It may be the seed is also dispersed in garden seeds.

Nodding foxtail does not do well in competition with well established perennial vegetation, and it appears to be vigorous primarily in clean-tilled crops. Its lush and rapid growth suggests the plant might have possibilities as an annual forage crop.

S. faberii is native to China. It has beeen known in the eastern United States since 1931 (2). Since then it has become widespread in the eastern states. The first known collection in Illinois was made in 1941 (1). Cursory inspection made during a trip across central Illinois and Indiana in September, 1950, show it is now exceedingly abundant on crop lands of those states, frequently blanketing soybean fields so densely that little else can be seen. The present known distribution of this species is from Pennsylvania to North Carolina; Massachusetts; Tennessee to Ohio; Illinois to Nebraska and Missouri.

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COMPARATIVE LEAF NUMBER IN THE EMBRYOS OF SOME TYPES OF MAIZE[1]

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Received December 19, 1950

The embryo of maize is morphologically mature when it has developed the maximum number of organs and the maximum tissue differentiation prior to germination. In many corn belt lines, the plumular axis of the mature embryo consists of the apical meristem and five foliage leaf primordia encased in the coleoptile. The plumule is more or less enclosed by the edges of the scutellum (Figs. 1–3). The root system consists of the primary root or radicle, encased in the coleorhiza, and three seminal roots at the upper region of the scutellar node. The above stage of development is attained approximately 40 days after pollination. The development of foliage leaves in the embryo has been reported in the literature, and described particularly well in Randolph's detailed embryological study (3). The reader is referred to Kiesselbach's comprehensive bibliography for the widely scattered sources of additional data (2).

Fairchild (1) has observed the consistent presence of five embryonic foliage leaves by the fortieth day after pollination in eight inbred lines of maize, and in the reciprocal crosses of the two lines that he studied in detail.

No comprehensive survey has been made of the degree of embryo differentiation in the mature kernel in lines and varieties that differ greatly in plant size, node number, life span, growth rate, and other plant characters. The present preliminary report includes a limited number of lines that exhibit some of these extremes.

MATERIAL AND METHODS

On the basis of height, node number, and earliness, Orchard Bay popcorn from North Dakota, and Alberta Flint were selected to represent short, very early lines.[2] Iowa 939, a double-cross, represents the tall, relatively late maturing corn belt type. An exotic corn, Guatemala 21 is a very tall maize with many nodes and a long life span.[3]

All samples were taken from kernels that had been shelled and

[1] Contribution from the Botany and Plant Pathology Section and the Farm Crops Subsection, Iowa Agricultural Experiment Station, Ames, Iowa. Journal Paper No. J-1878 of the Iowa Agriculutral Experiment Station, Project 1201.

[2] Obtained through the courtesy of Dr. J. C. Eldredge of the Agronomy Department.

[3] Obtained from the Pioneer Hi-Bred Corn Co. by courtesy of Dr. W. L. Brown.

dried, therefore the samples represented fully matured embryos. The kernels were soaked in 2 per cent sodium sulfite for 48 hours at 35°C. The embryos were extracted from the softened kernels, and the plumular axis was cut off and processed into paraffin. Transverse serial sections 12 microns in thickness were made between the stem tip and the coleoptile node. For the routine counting of leaves, the sections were stained in hemalum only. The few selected slides that were used for the photomicrographs were re-stained with a counterstain of safranin.

Two or three sections in the region of the node of the youngest leaf primordium provide accurate counts of leaf number. Counts may be made from a projected image, but with some experience the counts can be made by direct microscopic examination.

OBSERVATIONS

The cross sectional aspect of the embryo of a line of maize, collected 40 days after pollination and sectioned at the level of the stem tip, is shown in Fig. 1. In this well known corn belt inbred line, Os 420, the plumule is completely enclosed by the edges of the prominently keeled scutellum. Five foliage leaves are consistently present by the fortieth day, and this is the maximum leaf number in the mature kernel.

The following observations pertain to the plumules of dry, shelled kernels. A trial series of leaf counts was made on plumules of Iowa 939 to explore the range of variation in this character, and to arrive at a satisfactory sample size. Twenty plumules were sectioned serially, and without exception every plumule contained five foliage leaves (Table 1, Fig. 4). Because of this uniformity, only ten plumules of each of the other lines were sectioned.

TABLE 1

NUMBER OF FOLIAGE LEAVES IN THE EMBRYOS OF MATURE SHELLED KERNELS OF SOME TYPES OF MAIZE

	4 Leaves	5 Leaves
	(*kernels*)	(*kernels*)
Iowa 939		20
Guatemala 21		10
Orchard Bay Popcorn	1	9
Alberta Flint	10	

In view of the consistent presence of five embryonic leaves in the robust lines of the corn belt, the question arose whether the exotic giant types that have many nodes and a long life span have a more advanced embryo. The only material available, a Guatemalan variety, has five embryonic leaves (Fig. 3).

The two short, early lines that were selected for comparison differ strikingly from the foregoing lines in gross plant characters. Plants of Orchard Bay popcorn and Alberta Flint corn rarely exceed three feet in height, and have six to eight nodes above ground. As shown in Table

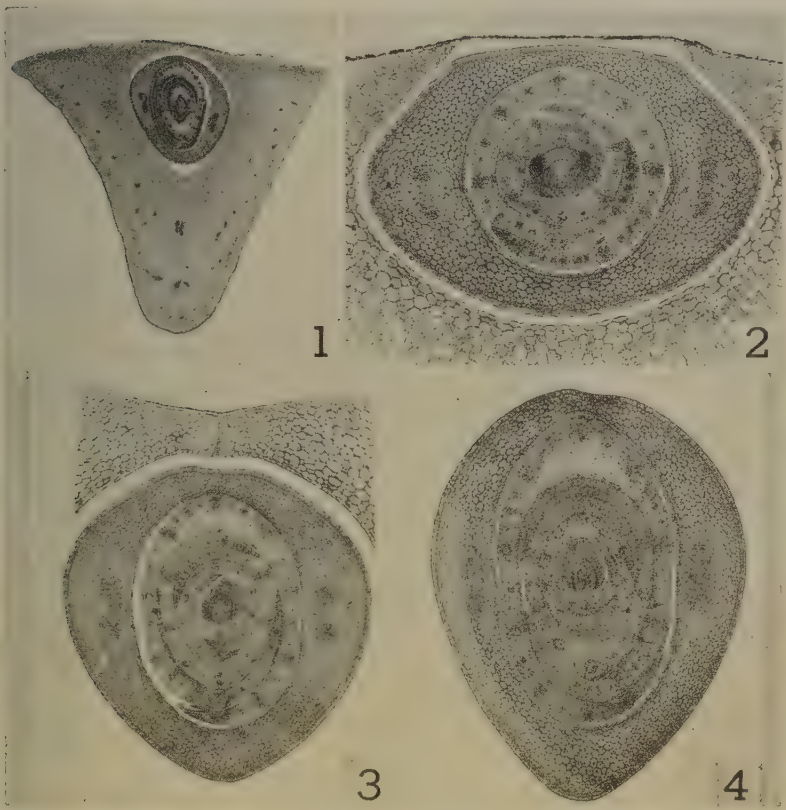

FIG. 1.—Transverse section of the embryo of inbred Os 420, 40 days after pollination. 15x

FIG. 2.—Plumule and portion of the scutellum of Orchard Bay popcorn, from mature kernel. 75x

FIG. 3.—Plumule and edges of the scutellum of Guatemala 21, from mature kernel. 50x

FIG. 4—Plumule of Iowa 939, from mature kernel. 60x

1, Orchard Bay popcorn has predominantly five embryonic leaves, whereas the equally dwarf Alberta Flint has four embryonic leaves.

DISCUSSION

Any comparative study of the rate of post-embryonic development of a species or other entity must take into account the status of the fully matured embryo. The present study has shown that some inbred lines and geographical varieties of maize differ with respect to the number of embryonic leaves in the dormant kernel. A study involving crosses between such dissimilar lines, and even a study of heterosis involving more

or less similar lines, should be based on a critical comparison of the initial embryonic capital. This may be expressed in the number of embryonic organs, size of these organs, or their degree of differentiation. The method of studying dissected embryos, as described herein, affords a method of making the essential pre-germination examinations.

SUMMARY

A study was made of the number of embryonic leaves in the fully matured, shelled kernels of some types of maize. The comparison included types that differ greatly in plant size, node number, and life span.

A very early and short inbred, Alberta Flint, has four embryonic leaves. An equally early and short inbred, Orchard Bay popcorn, has predominantly five embryonic leaves.

A robust double-cross, Iowa 939, which requires a full season to mature in the Corn Belt, has five embryonic leaves.

A very tall Guatemalan line that has a long life span has five embryonic leaves.

The number of embryonic leaves does not seem to be consistently correlated with earliness or final plant size. Therefore a determination of embryonic leaf number, as one aspect of meristematic capital, is essential in a genetic or morphogenetic study that involves this character.

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THE INITIATION OF THE INFLORESCENCE IN *BROMUS INERMIS* (LEYSS)[1]

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Received December 19, 1950

The breeders of forage grasses seek to develop strains that have desirable vegetative characteristics and also are good seed producers. Perennial forage grasses differ greatly with respect to the seed-producing ability of strains. Typically, grasses come into bloom during a narrow and specific period of the growing season, and the entire seed crop matures at essentially the same time. The final yield of seed may be influenced by many morphological factors, such at the ratio of flowering to vegetative stems, pollen and ovule abnormalities, and failure during the development of the caryopsis.

From a study of the flowering habits of grasses, it is evident that induction and development of inflorescences are controlled by the seasonal cycle of environmental factors. The present study of *Bromus inermis* was designed to determine the approximate time of inflorescence initiation in a number of clones in one geographical location. Such information is necessary for adequate interpretation of the effects of cultural treatments on induction and development of the inflorescence and production of seed.

REVIEW OF PERTINENT LITERATURE

Earlier studies of the grass inflorescence emphasized external morphology, vasculation and homologies of the organs of the inflorescence. This phase of the literature has been reviewed fully by Evans and Grover (4). The transformation of the vegetative apex into an inflorescence, and the successive emergence of organs on the inflorescence, has been described in a classic series of papers by Bonnet. Especially pertinent to the present study, are Bonnet's papers on barley (1), wheat (2), and oats (3), as well as the work of Evans and Grover (4) and Sharman (7) on several forage grasses, and of Knobloch (5) on *Bromus inermis*.

In the small grains and forage grasses, the vegetative apex is typically a smooth dome. Foliage leaf primordia arise at a relatively high level on the apex and elongate so rapidly that they soon arch over the stem tip. The transition to the flowering phase is characterized by rapid

[1] Contribution from the Botany and Plant Pathology Department and the Agronomy (Farm Crops) Department, Iowa Agricultural Experiment Station, Ames, Iowa. Journal Paper No. J-1879 of the Iowa Agricultural Experiment Station. Project 580.

[2] Research Professor and Graduate Assistant, respectively.

elongation of the apex into a cylinder. The first organs of the inflorescence axis are bracts, which first appear near the base of the axis, and are formed in acropetal succession. Lateral branch primordia appear in the axils of these bracts. The process of bract and axillary branch initiation progresses acropetally until the primary axis has become transformed to the flowering phase.

Histological details of the initiation of lateral primordia on the apex of *Agropyron repens* have been described by Sharman (7), who showed that a leaf is initiated by cell division first in the dermatogen, and later in the hypodermis. Axillary buds are initiated in the subhypodermis. Sharman reviewed the older literature on this phase of the problem.

MATERIALS AND METHODS

The plants used in this study were obtained from the breeding and test plots at the Agronomy Farm of Iowa State College through the courtesy of Dr. C. P. Wilsie. The clones were grown in replicated trials. In some plots the limits of the individual plants of the original planting were still evident; other plots were more or less solid sods. Short sprouts were removed close to the rhizome to insure including the growing points in the sample. Elongated sprouts were cut off above the highest elongated internode.

The plots were used for purposes other than the present study, so it was not desirable to dig up the sods for sampling. Therefore, samples were taken near the periphery of the sod, and the samples represent the sprouts of the active, spreading periphery of the plot rather than a random sample of the entire plot.

Samples for dissection required no preparation. Dissections of fresh sprouts were made under a stereoscopic binocular microscope, and the diagnoses were made in accordance with the sketches in Table 1. Samples that were to be stored and dissected at a later date were preserved in FAA, and transferred after several days, or even several weeks, into FAA containing 20 per cent glycerin added to the standard formula. By splitting fresh sprouts down the center, it was possible to estimate the position of the growing point and thereby to excise the portion of the sprout that included the node of the largest expanded green leaf, and a minimum of leafy material above the estimated position of the growing point. The pieces were evacuated in the preservative.

Tissues preserved in the FAA-glycerin formula yield fair microtome sections by the paraffin method. However, for a critical study of the cyto-histology of the activities of the stem apex, a Nawaschin modification (Craf 3) was used as a killing and storage fluid. Microtome sections were usually stained in safranin-fast green. For making projection drawings or photomicrographs, the cell walls were accentuated by a two-minute interval in hemalum, preceding the safranin.

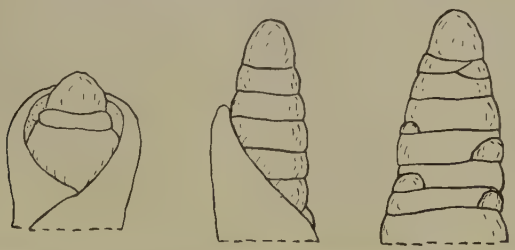
OBSERVATIONS

The aerial part of an established bromegrass sod in the dormant condition consists of the dried leafy culms of the previous growing sea-

son and the short green sprouts that will become the culms of the next season. Dissections and microtome sections show that the dormat sprouts are in the vegetative condition. The meristematic apex of the sprout is 3 to 5 mm. above the attachment of the sprout to the rhizome. The apex is a smooth dome, subtended by a series of encircling leaf primordia (Table 1; Fig. 1). The youngest leaf primordium, at the level of its attachment, extends slightly more than half-way around the stem. The successively older leaves show increasingly greater overlapping of their edges. No attempt has been made to determine the average number of foliage leaves and leaf primordia in dormant sprouts.

TABLE 1

RELATIVE DEVELOPMENTAL STAGES OF CULM APICES OF SEVEN CLONES OF BROMEGRASS COLLECTED ON THE SAME DATE, APRIL 20, 1949. THE SKETCHES WERE USED AS THE BASIS FOR DIAGNOSIS.



Number of Clones	Vegetative Axis	Elongated Axis	Panicle Branches
	(*apices*)		
284	8	4	13
469	6	4	14
470	1	1	23
471	0	4	21
489	13	8	3
547	2	5	14
568	1	1	22

The vegetative structure of the apex persists through the winter dormancy until early April, when the morphological initiation of the flowering phase occurs. Morphologically, the transition can be recognized by the marked elongation of the apical dome into a cylinder (Table 1). No more foliage leaf primordia are laid down after this transition has occurred.

The first lateral primordia of the elongated axis are bract primordia, formed at the base of the inflorescence axis. Several bract primordia arise acropetally before branch primordia become externally evident in the axils of the lowest bracts; however, sections show that the branches arise very early (Fig. 2). The formation of bract and branch primordia continues acropetally until the entire axis is transformed into floral

branches. The lateral branches, in turn, produce lateral primordia until the ultimate floret primordia are delimited.

The approximate dates of inflorescence initiation were determined by dissecting and sectioning stem tips collected at 2- to 4-day intervals during the critical period. Clone 284 was in the vegetative condition on April 4, 1949. The elongation phase of inflorescence initiation was evident on April 7, and by April 20, approximately two-thirds of a 25-sprout sample had well defined inflorescence primordia (Table 1).

FIG. 1.—Longitudinal section of apical meristem of vegetative sprout of *Bromus inermis*, collected June 21. Note foliage leaves and leaf primordia produced by vegetative apex. A vegetative bud is evident in the axil of an older leaf. 75x.

FIG. 2.—Longitudinal section of stem apex in transition to the flowering phase, collected April 12. 75x. L = foliage leaf, Bt = bract, Br = branch of panicle.

A preliminary survey was made of the comparative developmental status of seven clones at a given date. Collections were made on April 20, 1949. Twenty-five sprouts of each clone were taken for dissection, but some mishaps occurred during dissections. The results are shown in Table 1. The rough sketches of stem apices shown in this table are used as standards for diagnosis in this kind of study. The seven clones showed some differences in the rate of inflorescence development. Clone 568 was most advanced, 489 was most retarded, and 284 was intermediate during that particular year. Approximately one-fifth of the sprouts of the combined samples were still in the vegetative condition. However, four of the clones had nearly completed the transition to the flowering phase.

Another series of observations of inflorescence initiation was made

in the spring of 1950. Three clones were selected on the basis of their behavior during the previous year. On April 4, 1950, clone 489 was entirely vegetative, 568 was in the early elongation phase, and 284 showed advanced elongation of the apex. On April 12, clone 489 was still vegetative, whereas 568 and 284 had well defined branch primordia in the axils of bracts. By April 19, clone 489 had also shifted to the flowering phase.

The flowering dates of these clones for the summer of 1950, supplied by Dr. Robert R. Kalton, are as follows:

Clone 469 — June 16
Clone 568 — June 19
Clones 470, 471, 489 — June 21

The cyto-histology of the initiation of primordia on the floral axis, and the development of the various categories of organs on this axis, will be described in a subsequent report. Attention is now directed to the status of the stem apex in late autumn. The new sprouts that develop from the rhizomes during the summer range from white, underground sprouts, to emerged, green leafy stems. A sample of 50 sprouts of clone 284 was collected after the first hard freeze of 1948, which occurred at the experimental plots on October 17. Only five inflorescence primordia were found in the sample of 50 sprouts, and these primordia occurred on the emerged green sprouts. These primordia ranged from pale tan to dark brown in color, in striking contrast to the glistening, translucent appearance of the live apices, which were all vegetative on the above date.

Collections made in January of 1950 had either fresh, shiny vegetative apices, or a brown, necrotic apical zone in which organs or primordia could not be distinguished. There is little doubt that the rare inflorescence primordia that are evident in late autumn do not survive the winter.

DISCUSSION

A study of the developmental morphology of the inflorescence is a prerequisite to a critical study of the seed production problem in perennial grasses. It is desirable to know the "normal" sequence of development of foliar and floral organs and the seasonal cycle of these processes. Such basic information permits sound interpretation of the effects of marked deviations from mean weather conditions, or of experimental manipulations of environmental conditions.

It is especially important to use morphological data to insure correct use of three loosely used terms, induction, initiation, and development of the flowering phase. Emergence of panicles is evidence that floral induction had occurred at some previous time [Metcalfe (6)], but the determination of the specific time of histological initiation and the order of development of floral organs can be based safely only on actual microscopic study, in dissections, and serial microtome sections.

The flowering dates of the clones used in this study do not follow

the same order as the dates of floral initiation. The developmental events from initiation of the inflorescence to anthesis are probably controlled by a complex of genetic and environmental factors, and the lack of parallelism between the time of initiation and the time of anthesis is not unexpected. Observations over a period of years would be necessary to establish a reliable correlation.

A comparative study of strains or varieties should seek to determine potential and actual flowering capacity, in terms of the ratio of vegetative culms to culms that initiate inflorescence primordia, as well as the ratio of emerging inflorescences, and finally of seed-producing panicles. The present study has demonstrated clonal and seasonal differences in the time of floral initiation, but the quantitative aspects of the problem deserve further study with better sampling techniques. The sampling methods used in morphological study are in a primitive state, in terms of modern statistical plot techniques. This does not invalidate the morphological facts, but quantitative implications are being made with caution until sampling methods are devised that will bear statistical scrutiny.

SUMMARY

The initiation and early stages of development of the inflorescence was studied in seven clones of *Bromus inermis*.

Bromegrass produces leafy sprouts from the rhizomes during the growing season. The growing points of these sprouts are predominantly in the vegetative condition during the growing season. The rare inflorescence primordia that are formed in late autumn do not survive the winter.

Transition of stem apices from the vegetative to the flowering phase occurs from early to mid-April in the Ames, Iowa area. Transition is recognized by the change of form from a dome-shaped, short growing point to an elongated, cylindrical inflorescence axis. Lateral primordia of bracts, and their axillary secondary axes, develop on the central axis in acropetal succession. Complete transformation of the stem tip into a floral axis occurs within two weeks after the transition is initiated.

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ELECTROPHORETIC STUDIES ON SWINE
II. THE COMPOSITION OF PLASMA DURING GESTATION AND LACTATION [1]

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Received December 29, 1950

As part of a broad program concerned with the effect of nutrition on baby pig livability, the protein composition of the plasma of a large number of sows on known diets has been traced through gestation and lactation.

Various investigators (2, 5, 6) in the field of human serology have adequately demonstrated that total plasma protein and albumin decrease and the globulin components remain constant during pregnancy. Longsworth (4) has determined that maternal plasmas are below normal in albumin and gamma globulin and high in alpha and beta globulin. Lagercrantz (3) reports similar results in both relative and total concentrations.

EXPERIMENTAL

EXPERIMENT I

Four sows were selected for experimentation. Two of these were from a group receiving a basal ration of yellow corn, soybean oil meal, minerals, and vitamins and two from a group receiving the basal ration fortified with alfalfa meal and meat scraps. These sows were started on the special ration at the beginning of gestation and were from the same group which had been previously used to establish a normal electrophoretic pattern (1).

Blood samples were collected from the sows by bleeding from an ear vein as described in the first paper of this series (1). The samples were collected 24 hours after farrowing and once a week thereafter for three weeks and again at eight weeks at which time the pigs were weaned. The formed elements and plasma were separated by centrifugation and the plasma preserved by freezing. Since in most instances it was found that fibrin clots had formed, results of this experiment are presented on a fibrinogen-free basis.

Electrophoretic analyses were made on a 1:4 dilution of the plasma using a phosphate plus chloride buffer of *p*H 7.6 and total ionic strength 0.18. The electrophoretic technique has been previously described (1).

[1] Journal Paper No. J-1794 of the Iowa Agricultural Experiment Station, Ames, Iowa. Project 959.

[2] The authors are indebted to Swift and Company for financial assistance and to Paul Homeyer for advice in the interpretation of data.

EXPERIMENT II

The second group of swine selected for experimentation consisted of twelve gilts which had been on continuous drylot on adequate rations containing animal protein, dehydrated alfalfa meal, and trace minerals. They were divided into four lots of three each and fed a basal ration of yellow corn, soybean oil meal, dehydrated alfalfa, vitamin D_2, limestone, steamed bone meal, and salt. Sows in Lot I received no trace minerals, those in Lot II received a 1x level, those in Lot III a 2x level, and those in Lot IV received a 3x level of a trace mineral mix consisting of the sulfates of iron, potassium, copper, manganese, cobalt, and zinc.

Ten milliliters of blood were collected from each gilt at the time of breeding and every two weeks thereafter and a final sample on the 112th day of gestation. The samples from each lot were pooled for electrophoretic analyses during the gestation period. One sow was selected from each lot at the time of farrowing for continuation through lactation. Blood samples were collected from the sows 24 hours after farrowing and at seven-day intervals thereafter for three weeks with the final sample at eight weeks after farrowing. During gestation the blood samples were collected by amputating the tail and collecting 10 ml. of blood in an equal volume of a saturated solution of sodium oxalate. During the lactation period the sows were bled from an ear vein.

The treatment of the blood samples was the same as previously described (1) with the exception that the plasma was preserved by lyophilization. The concentration of plasma samples used for electrophoretic analysis was carefully controlled by diluting to a constant refractive increment of 0.0020 corresponding to a protein concentration of 1.0 per cent as outlined in the first paper of this series (1).

EXPERIMENT III

The eight sows selected for this experiment had been on different but adequate diets. At the initiation of the gestation experiment they were divided into two lots, of four sows each. Lot I received a relatively poor ration consisting of yellow corn, soybean oil meal, limestone, bone meal, and salt. Lot II received a highly nutritious ration containing in addition condensed fish solubles, dehydrated alfalfa meal, vitamins A and D_2, riboflavin, and trace minerals. Samples were taken from the ear veins and either run immediately or lyophilized. Conditions for electrophoresis were as in Experiment II.

RESULTS AND DISCUSSION

The data are presented in graphic form in order to illustrate more clearly the trends of the various plasma components during gestation and lactation. (Figs. 1, 2, 3, and 4.)

These results show that the total protein decreases gradually during gestation and sharply during the first 24 hours postpartum. Contrary to the trend seen in the albumin concentration of human plasma, the relative concentration in swine plasma remained quite constant during

the gestation period. Gamma globulin was the only component which showed a marked downward trend in both relative and total concentration throughout the gestation period.

The trends of the total plasma protein and the plasma components may be summarized as follows:

1. Total protein. As shown in the precediing paper of this series, the determination of total protein is subject to somewhat larger relative errors than is the determination of relative composition. Furthermore, it was shown that there are very large individual variations in total plasma protein, sixteen analyses on eight normal adult females yielding an average figure of 67.4 mg./ml. with a coefficient of variation of 19.0 per cent. Nevertheless, when it is considered that the results in Fig. 2 represent averages of four separate measurements on pools representing

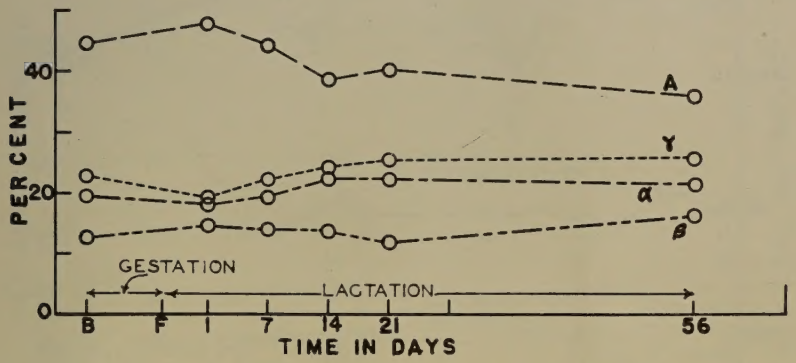

FIG. 1.—Relative composition of proteins (per cent) in sow serum at breeding and through lactation. Average of results on four sows in Experiment I. Abscissa is non-linear. *B* and *F* are breeding and farrowing times.

three individuals each, and Figs. 3 and 4 the average of four individual results each, it would appear that they should be fairly reliable. There is remarkably good agreement between Figs. 3 and 4 (Experiment III, good and poor rations), the total protein being initially much higher than normal (a fact which cannot at present be explained) and dropping to only slightly subnormal at farrowing. In Fig. 2 (Experiment II) the pattern is much different, the initial level being normal, followed by a sharp rise at 35 days which holds to 112 days. At farrowing the figure is once again just about normal.

There was a very marked decrease in total protein during the first 24 hours postpartum in all three instances. These concentrations increased to approximately the immediate prepartum level after seven days. The total protein concentration in Experiment II increased until the fourteenth day of the lactation period then decreased from 88.5 to 67.5 mg. per ml. during the remainder of the period. The concentrations

increased slowly during the remainder of the lactation period for both groups in Experiment III.

2. Albumin. The relative concentration of this component fluctuated in a variable manner during early gestation, then remained fairly constant until parturition. With the exception of the poor ration of Experiment III (Fig. 3) there was a slight increase at parturition. In all experiments there was a downward trend during the lactation period.

3. Alpha-globulin. This component of swine plasma was reasonably constant in relative concentration during gestation, but was variable

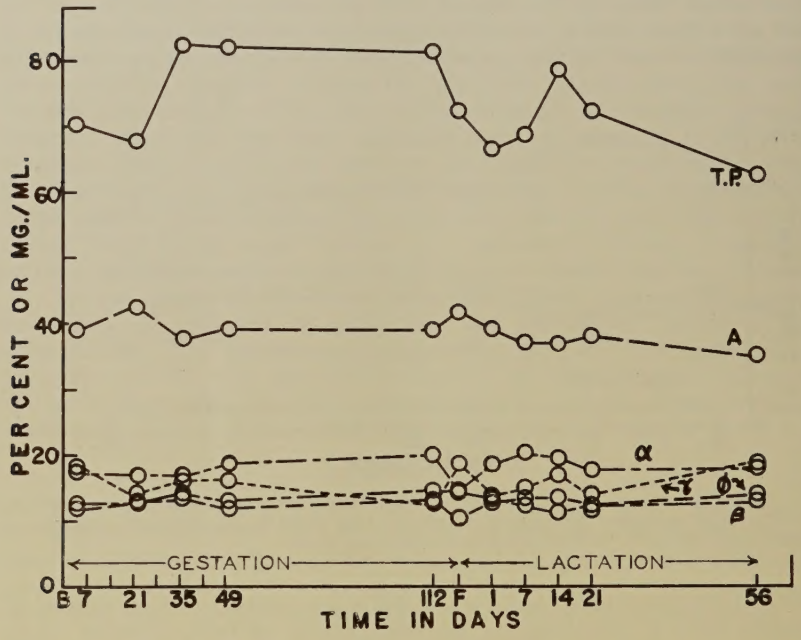

FIG. 2.—Relative composition of proteins (per cent) and total protein concentration (mg./ml.) of sow plasma through gestation and lactation. Average of results on four sows in Experiment II. Abscissa is non-linear.

during early lactation. In Experiment I (Fig. 1) it was low at one day postpartum, increased until fourteen days and then remained constant. In Experiment II (Fig. 2) there was a marked decrease at parturition and a return to normal by the seventh day of lactation. In the good ration of Experiment III (Fig. 4) there was a dcrease in concentration on the seventh day of lactation followed by a return to normal. In the poor ration group of this experiment the concentration was irregular during the lactation period.

4. Beta-globulin. This component was comparatively constant in relative concentration throughout the entire gestation-lactation period.

5. Fibrinogen. This component also showed little variability in relative composition during the gestation-lactation period. There was a slight decrease in relative concentration in Experiment II at parturition and in animals on the good ration of Experiment III at one-day postpartum.

6. Gamma-globulin. There was a downward trend of the relative

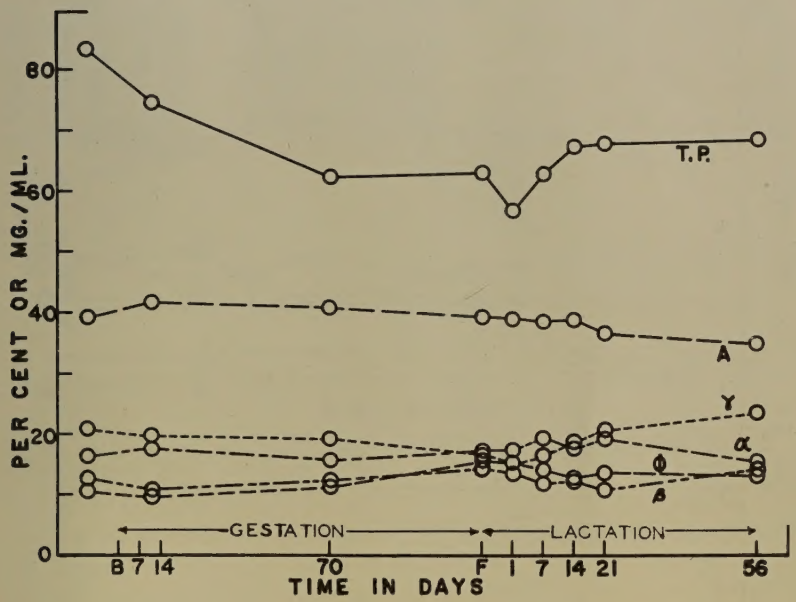

FIG. 3.—Relative composition of proteins (per cent) and total protein concentration (mg./ml.) of sow plasma through gestation and lactation. Average of results on four sows on poor ration of Experiment III. Abscissa is non-linear.

concentration of this component during gestation in all the experiments. In each instance there was a low point 1 day postpartum followed by an increase in concentration throughout lactation. This component differed in Experiment II (Fig. 2) in that there was a low point at the 112th day of gestation, a marked increase at parturition followed by decreases one day and twenty-one days postpartum.

SUMMARY

The results of 120 electrophoretic analyses tracing the variations in protein composition of the plasma of female swine through gestation and

lactation are reported. In terms of relative composition the albumin, fibrinogen, and α- and β-globulin show no significant trends. The γ-globulin component, on the other hand, declines in both relative and

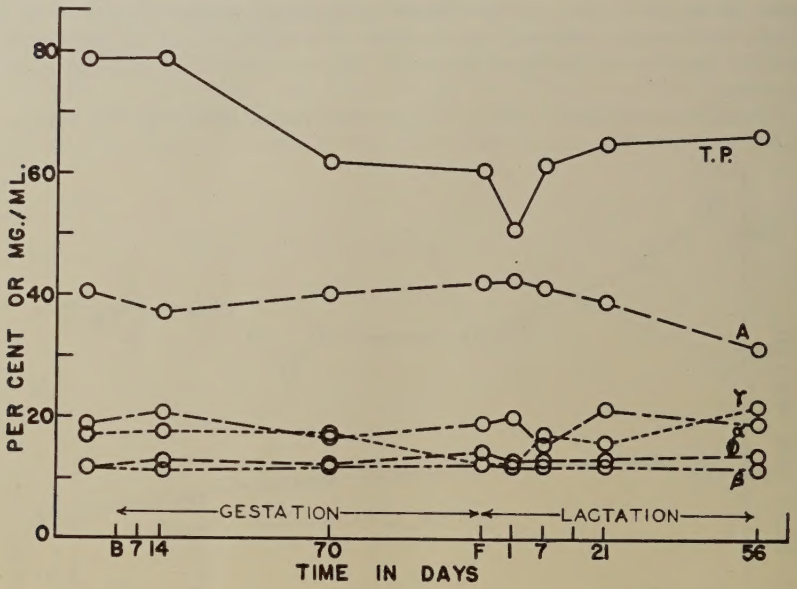

FIG. 4.—Relative composition of proteins (per cent) and total protein concentration (mg./ml.) of sow plasma through gestation and lactation. Average of results on four sows on good ration of Experiment III. Abscissa is non-linear.

absolute concentration throughout gestation and usually more sharply during the first 24 hours postpartum followed by a gradual rise to the normal level. Dietary influences over the range of rations studied are not significant.

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